DOCUMENT RESUME

ED 272 708 | CE 044 807

| | |
|---|---|
| TITLE | Electrician (AFSC 54250). |
| INSTITUTION | Air Univ., Gunter AFS, Ala. Extension Course Inst. |
| PUB DATE | 82 |
| NOTE | 697p. |
| PUB TYPE | Guides - Classroom Use - Materials (For Learner) (051) |
| EDRS PRICE | MF04/PC28 Plus Postage. |
| DESCRIPTORS | Alarm Systems; Behavioral Objectives; Correspondence Study; *Electrical Systems; *Electric Circuits; *Electricians; *Electricity; *Electric Motors; Electronic Control; Electronic Equipment; Equipment Maintenance; Equipment Utilization; Learning Activities; Military Personnel; Military Training; Postsecondary Education; *Trade and Industrial Education |
| IDENTIFIERS | Air Force; Military Curriculum Materials |

ABSTRACT

This three-volume student text is designed for use by Air Force personnel enrolled in a self-study extension course for electricians. Covered in the individual volumes are general subjects (career progression, resource management, supervision and training, and safety and first aid); basic electricity and installation of electrical systems (basic electricity; electrician's tools; electrical materials and devices; installation of services and distribution panels; procedures for planning and laying out work; circuit installation with nonmetallic cable and conduit; meters and test equipment; and distribution system maintenance, troubleshooting, and repair); and installation of motors, controls, and special equipment (motors and motor control circuits, systems in hazardous locations, special equipment, cathodic protection systems, fire alarm and intrusion alarm systems, contingency responsibilities, and contingency training). Each volume in the set contains a series of lessons, exercises at the end of each lesson, a bibliography, and answers to the exercises. Volume review exercises and a change supplement for the package are also included. (MN)

ELECTRICIAN

(AFSC 54250)





Extension Course Institute
Air University

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| 5 | VOL | VOL 2, Basic Electricity and Installing Electrical Systems | 54250 02 8210 | |
| 6 | VRE | VOLUME REVIEW EXERCISE (VOL 2) | 54250 02 21 | 54250 02 21 |
| 7 | VOL | VOL 3, Installation and Maintenance of Motors, Controls, and Special Equipment | 54250 03 8211 | |
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.. CHANGE FOR THE SUPPLEMENT: 54250 00 S01 8406

Supplement page 2, pen-and-ink change for page 84L: Delete.

. CHANGES FOR THE TEXT: VOLUME 1

a. Page [illegible] 3 fr bot: Change "33 hours (11 points)" to "24 hours (8 points)."

b. Page 64, col 1, lines 10-last: Delete "3-1. Supervisio[illegible] our superior, you." Col 2, lines 1-last: Delete "jeopardize your own . . . equipmen[illegible] appliances.

c. Pages 65-84: Delete pages in their entirety.

d. Page 85, Exercises (056)-5 & 6: Delete.

e. Page 142, answers 042-1 thru 044-1.b: Delete.

f. Page 143: Delete page in its entirety.

g. Page 144, answers 053-3 thru 056-6: Delete.

3. CHANGES FOR THE TEXT: VOLUME 3

a. Page 76, col 2, line 20: Change "electrical inspection" to "contract management."

b. Page 147, col 2, line 17 fr bot: Change "five" to "six."

4. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 1

The following questions are no longer scored and need not be answered: 40 thru 58 inclusive.

5. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 2

Page 17, question 114, choices a, b, c and d: Change "shunt" to "unit."

6. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 3

The following questions are no longer scored and need not be answered: 28, 32, 82, 88 and 93.

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# ELECTRICIAN

(AFSC 54250)

Volume 1

*General Subjects*

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THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

# Preface

NOW THAT YOU started training for your 5 level Electrician Speciality, you should be aware that most Air Force people depend upon you for electrical service. Your main responsibility is learning your craft and assuming the duties of a competent electrician. This self-study course provides all the needed information required to perform your work correctly and safely.

In this volume, Chapter 1 covers the organizational structure of the Air Force base civil engineering unit, your career progression and duties, security, and publications. Chapter 2 lists and describes work authorization documents and gives property accountability and responsibility. Chapter 3 emphasizes on supervision and training. Chapter 4 is a discussion on the proper safety procedures and use of tools used in this field, and first aid necessary to save a life.

Code numbers appearing on figures are for preparing agency identification only and should be of no concern to the student.

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Direct your questions or comments relating to the accuracy or currency of this volume to the course author: 3700 TCHTW/TTGXF, ATTN: MSgt Jerome E. Pollock, Sheppard AFB, Texas 76311. If you need an immediate response, call the author, AUTOVON 736-2087 or -6283, between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

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This volume is valued at 33 hours (11 points).

Material in this volume is technically accurate, adequate, and current as of November 1981.

# Contents



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**NOTE: In this volume, the subject matter is developed by a series of student-centered objectives. ...ch of these carries a three-digit number and is boldface ...e. Each sets a learning goal for you. The text that follows the objective ... info...ation you need to reach that goal. The exercises following the information give ... ...ck on your achievement. When you complete them, see whether your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.**

# CE Organization, Career Progression, Security, and Publications

THERE ARE MANY base facilities used by the Air Force to carry out its mission. Each one of these facilities depends on electricity to carry out its daily activities. This electricity may be essential to certain base activities to operate computers, radar systems, or security systems. While at other activities, electricity may only be necessary for lighting and comfort. Whatever the case may be, you have one of the most important jobs in the Air Force. You will be a crewmember or lead a crew in installing and maintaining the interior wiring systems in base facilities.

This chapter presents an overall picture of a civil engineering (CE) organization. It also covers your career progression, communications and operations security, and publications of particular value to you.

## 1-1. Civil Eng...r... Organization

Th... ...ering organization on an Air Force base is responsible for the upkeep of the base. This means maintaining all base facilities to their fullest operational level. If the lights go out in a building, that building is no longer operational. People cannot work in the dark. You, the CE electrician, must get the lights back on. If a building is being flooded with water, the plumbing shop will have to shut the water off and repair the plumbing that caused the problem. If a lawnmower throws a rock through a plate glass window, the CE carpenter shop will make the necessary repairs. If a transformer burns out, causing all the electric power in a block to go out, the exterior electric shop gets the power back on. There are hundreds of things on the base that need maintenance, repair, or replacement each day. In every case, there is a CE specialist to see that it gets fixed. CE is an efficient but very complex organization. To get a closeup view of CE, let's first look at the overall mission and then examine its organizational structure.

**001. From a list of maintenance activities, select those that do not pertain to the overall mission of a civil engineering organization.**

**Base Civil Engineering Mission.** The primary mission of the civil engineering organization is to acquire, construct, maintain, and operate real property facilities on the base. To understand what this means, you must know what the Air Force means by real property facilities. The word "real" is a short word meaning real estate. Real estate property facilities on an Air Force base are the things that are of a permanent nature and for which the Congress has appropriated funds. For example, real property includes land, buildings, water, gas, sewage ... pl...ts, pavements, and railroads. Examples of ... ...hat are not classified as real property include aircra... ...ssiles, NCO ...lub equipment, and bowling alley equipme...

Although an aircraft is not ...nsidered real property, the building that houses the aircraft and the equipment needed to operate the building are real property. The CE organization does not service, maintain, or repair the aircraft. It does, however, maintain the hangar and the real property installed equipment (RPIE). In addition, CE provides the facility with water, gas, electricity, heating, cooling, and sewage disposal. Nonappropriated fund property on base is not real property. That is, CE is not accountable for this property. Examples of this type of property include the equipment in the NCO club, bowling alley, and base exchange. Civil engineering furnishes these facilities with utilities and it does perform maintenance for them, but those facilities must refund the costs of those services to the Air Force.

As part of the primary mission of base civil engineering support, CE also performs services such as fire protection, entomology, landscaping, ground maintenance, and work connected with base recovery from natural and manmade disasters.

**Exercises (001):**

1. In the exercises below, place an X beside the maintenance activities that are NOT the responsibility of a CE technician.

____ a. The exterior walls of the base hospital require painting.
____ b. An electric motor operating a pin-changing machine in the bowling alley has burned up.
____ c. The primary fuse on a transformer serving the BX has blown.
____ d. The roofing on one of the houses in the base housing area needs replacing.
____ e. The auto-hobby shop needs a larger special-purpose outlet to handle the load for new machine shop equipment.
____ f. The landing gear on an aircraft needs to be serviced.

**002. Given a civil engineering organizational chart, list the command block above given units.**

**Civil Engineering Organization.** You will be working with other shops within the CE organization as well as with your crewmembers. You need to know the line of command in the CE unit in order to coordinate your shop functions with other shops in your unit. Figure 1-1 shows the chain of command from the Base Civil Engineer (BCE) through your shop. This chart may differ from the organizational chart of your own unit due to economic and geographical limitations. The organizational elements within the major functional areas may be vertically expanded or contracted to meet the needs of your base.

Study this chart and compare it to your organizational chart and you will gain a better knowledge of where you are in the CE organization. You work out of the interior electrical shop. Locate your shop on the chart. As you can see in figure 1-1 your shop is one of two under the electrical block. In some cases the power production block is combined with the electrical block. Each shop will have a supervisor known as the shop supervisor. You will work for the electrical shop supervisor.

The shops under each block are directly responsible to a superintendent. The interior and exterior electrical shops are responsible to the electrical superintendent. Your supervisor, the interior electrical shop supervisor, is responsible to the electrical superintendent. If you follow the line of command up the chart, the next block is the operations block. The operations and maintenance (O&M) chief is over all the section superintendents, including the electrical superintendent.

The resources and requirements section is a staff agency that works for the O&M chief and is there to help the other sections. The section chiefs are not responsible to the resources section but use this section to get their jobs done.

The next command block up from the operations block is the civil engineer. As you can see from the chart, the BCE holds the chief of operations responsible for all those units on the command line below operations. The CE organization is headed by an officer, usually a professional civil engineer, who is designated as the BCE. The BCE is responsible for the overall planning, directing, supervising, and coordinating of all CE activities on the base. This person is directly responsible to the base commander.

The part in figure 1-1 that is enclosed in dotted lines represents Energy Monitoring and Control Systems (EMCS). It is enclosed in dotted lines because it may fall under several areas in the organizational chart. It is a new shop and may not be found at all bases. Until further experience gives a basis for a specific, standard organization, EMCS Operations, Instrument Control, and Electronic Control functions may be set up as individual work centers under the O&M section (i.e., Mechanical, Electrical) or combined with other subelements within O&M.

The hospital maintenance and family housing maintenance blocks also come under the control of the chief of operations. These two blocks are made up of people from several shops and thus are not directly under the control of any one shop.

**Exercises (002):**

1. Using the CE organizational chart in figure 1-1 list the command block for each of the following units.

| *CE Unit* | *Next Command Block* |
|---|---|
| a. Heat systems. | |
| b. Operations. | |
| c. Planning. | |
| d. Exterior electrical. | |
| e. Resources and requirements. | |
| f. Family housing maintenance. | |
| g. Electrical. | |
| h. Interior electrical. | |
| i. Electrical ...er production. | |
| j. Housing. | |

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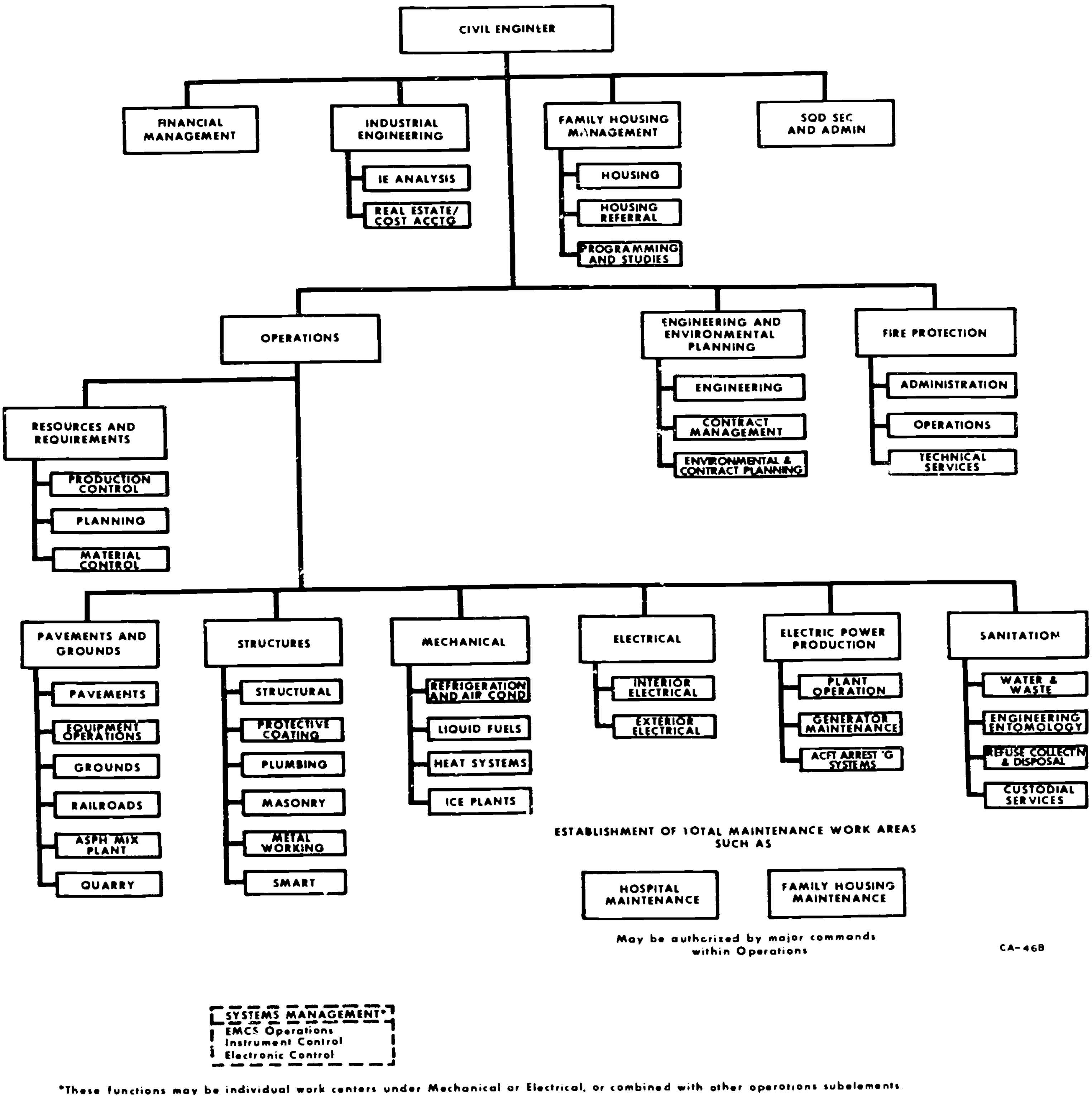


Figure 1–1. Base Civil Engineer Organizational Chart.

**003. Associate a representative list of functions and responsibilities with their CE unit.**

**Functions and Responsibilities of the BCE.** Base civil engineers plan, direct, supervise, and coordinate, all CE activities in the broad areas outlined below:

*a*. Management of Air Force real property.

*b*. Provision of utilities.

*c*. Maintenance and repair of structures and equipment.

*d*. Provision of custodial, sanitation, and entomological services.

*e*. Fire protection and rescue.

*f*. Recovery from damage to facilities from any cause, including decontamination assistance in recovery from chemical, biological, or radiological incidents or attacks.

*g*. Management of the base engineer emergency force (BEEF) program, as required by AFR 93–3, the Prime BEEF Program.

*h*. Accomplish disaster preparedness actions and provide assistance in disasters.

*i*. Reports, through the Air Force Operational Reporting System, any installation damages to airbases, and assistance and funding required to recover airbases.

*j*. Environmental protection.

*k*. Natural resources.

*l*. Construction and alternation of structures.

As you can see, the BCE's functions and responsibilities are broad in scope and are difficult, if not impossible, to accomplish without a highly structured organization. To help the BCE carry out his or her responsibilities, the units shown in figure 1-1 were developed.

**CE Units.** The major units covered under this objective are Squadron and Administration, Industrial Engineering, Financial Management, Family Housing Managment, Operations, Resources and Requirements, Engineering and Environmental Planning, and Fire Protection.

*Squadron and Administration*. This unit, often called the orderly room takes personnel actions that are delegated by the squadron commander. Some of these functions include counseling, squadron duty rosters, general military training, commander's call, and disciplinary action. Areas the orderly room may help you with are issuing a meal card, assignment to a room in the dormitory, or processing a leave request. The squadron commander is assisted by the first sergeant and chief clerk. In very small units the BCE often acts as the squadron commander.

The administrative part is responsible for the administrative work of the civil engineering organization. This section receives, distributes, and dispatches all communications for CE. It also prepares and maintains reports and correspondence, as well as maintaining the CE library. In addition, it conducts special programs, such as fund drives and awards. The administrative section also supervises the records.

*Industrial Engineering (IE)*. There are two sections located within IE: Industrial Engineering Analysis and Real Estate/Cost Accounting. The IE analysis unit accumulates data from CE records, reports, and other sources. It analyzes this data to see if the CE units are producing according to Air Force standards. Where units are operating below standards, IE Analysis makes recommendations to the industrial engineer for improvements.

The real estate/cost accounting section plans, develops, and coordinates programs for the aquisition (that is fee title, lease, easement, permits, and so forth), accountability, reporting, and disposition of real property. They also advise the civil engineer officials on all matters pertaining to cost accounting.

*Financial Management*. This unit serves as advisor to the BCE and provides advice on all financial matters. It develops, prepares, and maintains the financial plan and budget estimates.

*Family Housing Management*. There are three sections within Family Housing Management: Housing, Housing Referral, and Programming and Studies.

The Housing section manages all operations associated with on-base family housing. Housing Referral maintains a list of suitable community housing. It provides counseling and information on off-base housing as well as information on schools, churches, shopping centers, and other community support facilities and services. Programming and Studies is responsible for family housing requirements surveys and development of data. It also plans and programs for new family construction and improvements.

*Fire Protection*. Administrative, Operations, and Technical Services fall within the Fire Protection block. The Administrative unit takes care of all administrative jobs for the fire protection block. One of its jobs includes maintaining records and reports on fire incidents, personnel, and supply matters. It also makes sure that personnel receive the proper training associated with fire protection.

The Operations unit operates firefighting facilities, including fire alarm communications, and dispatches firefighting and rescue equipment and vehicles.

Technical Services is responsible for fire inspections and the fire prevention program as well as developing base fire regulations.

*Engineering and Environmental Planning*. From figure 1-1, you can see that there are three units in this block: Engineering, Contract Management, and Environmental and Contract Planning.

Engineering handles the architectural and professional engineering services for CE. Problems that are beyond the capabilities of operations and maintenance people are referred to the professional engineers. This unit reviews and develops technical provisions of contracts for real property facilities.

Contract Management inspects maintenance, repair, construction, and service work done by contract. It also provides technical advice on proposed new construction, and changes and repairs to existing facilities.

Environmental and Contract Planning is responsible for conserving and managing natural resources as well as the environment.

*Resources and Requirements*. Within this section of the command block are three units: Production Control, Planning, and Material Control.

Production Control receives and approves all work requests and determines the method of work

accomplishment. It also prepares and maintains the in-service work plan and weekly as well as daily schedules. In addition, it controls vehicle assignment and utilization, and manages the taxi system.

Planning works with Production Control in the preparation of work orders and job orders. It also inspects facilities for maintenance and repair requirements. Another job it performs is the preparation of cost estimates for in-service work requests.

Material Control does just what the name implies: it controls and directs material support activities for all items of supply.

*Operations*. This command block is responsible for directing the activities of the Chief of Resources and Requirements, Operations Superintendents, and the Chief of EMCS. They also manage Prime BEEF, contingency planning, disaster recovery, and readiness programs. The superintendents from Pavements and Grounds, Structures, Mechanical, Electrical, Electric Power Production, and Sanitation are all responsible to the Chief of Operations. Each of these areas may contain several shops; for instance, the electrical area has the Interior and Exterior Electrical Shops. You are assigned to the Interior Electric Shop. As we stated earlier, this shop is under the command of the shop foreman who is under the electrical superintendent.

NOTE: Each section listed in this objective has many jobs too numerous to list. Some of their jobs are listed here, but by no means should they be used as a check list of mandatory performance items. A more detailed list of jobs or functions may be found in AFR 85-10, *Operation and Maintenance of Real Property*.

**Exercises (003):**

1. Match the CE unit in column B with the function and responsibility in column A by placing the letter in the space provided.

| *Column A* *Function and Responsibility* | *Column B* *CE Unit* |
|---|---|
| ____ (1) Manages Prime Beef. | a. Squadron. |
| ____ (2) Manages taxi system. | b. Administration. |
| ____ (3) Responsible for fire prevention and protection program. | c. Industrial Engineering. |
| ____ (4) Reviews technical provisions of contracts for real property facilities. | d. Operations. |
| ____ (5) Manages operations of family housing. | e. Fire Protection. |
| ____ (6) Conducts fund drives. | f. Family Housing Management. |
| ____ (7) Conducts military training. | g. Financial Management. |
| ____ (8) Manages financial matters. | h. Resources and Requirements. |
| ____ (9) Maintains electricity on base. | i. Engineering and Environmental Planning. |
| ____ (10) Analyzes data and makes recommendations for improvement. | |

**004. State the mission of Prime BEEF, deployment procedures, composition of teams CF-1 and CF-2, and training requirements.**

**Project Prime BEEF.** Prime BEEF team members are assigned to the base civil engineering organization as a part of the normal operation and maintenance work force. The Prime BEEF program is set up to use military personnel for peacetime real property maintenance and, at the same time, be prepared to support wartime or contingency requirements.

In the 60's the program had two types of teams: mobile and nonmobile. Mobile teams (contingency and Flyaway) were designed to support worldwide contingencies, special air warfare operations, and disasters. The nonmobile teams were Recovery (R) and Missile (M) teams. The "R" team provided a military capability to operate bases during enemy attack, sabotage, natural disasters, major accidents, and civil disturbances.

In the mid 70's, war plan emphasis changed from a strategic nuclear war plan to a plan based on a conventional war. A larger mobility force is required for this type of plan. The number of mobile teams was increased to meet the workload. The primary responsibility for operating maintenance and recovery of stateside bases during wartime is now the responsibility of the civilian work force, with the help of contractors. All military personnel are designated as deployable resources except for some civil engineers who are required for direct combat support within the United States. Team members are placed by skills and trained for deployment.

The Prime BEEF force is made up of all military in CE. Each military person will be assigned to a Prime BEEF team. In the event of an enemy attack, a natural disaster, or an emergency workload, at either a stateside or an overseas base, a BEEF team can be made available to supplement the work force at the affected base. There are a number of Prime BEEF teams that will be covered in this objective, but first, you should become familiar with the mission of the Prime BEEF teams.

**Mission of Prime BEEF.** The mission of Prime BEEF teams is to perform direct combat support roles in support of the Air Force mission worldwide and to provide a mobile rapid response capability. Overseas, Prime BEEF forms the nucleus for recovery of all base facilities following an attack, disaster, or other emergency. These Prime BEEF teams maintain essential base operations and maintenance service before, during, and immediately after an attack or during a major fire, flood, storm, strike, or other similar emergency. In the CONUS, civilian employees will provide such service if the Prime BEEF team is deployed. In a situation at their home base that would require a BEEF team, the concept will be the same as for overseas locations. Coordinated mobility enables the military to move from place to place while retaining the ability to fulfill their primary mission.

Members assigned to a mobile Prime BEEF team must be equipped to perform in their AFSC specialty when deployed. Team members will have a mobility bag containing their personal clothing and a tool kit. The tools will conform to the list given in attachment 1 of AFR 93-3.

**Deployment.** During peacetime deployment, Prime BEEF mobility teams may either stay in the same team or be put in with another CE unit or RED HORSE unit as needed. These teams may be attached to the augmented unit as a separate work element, if directed by the gaining organization. The augmented unit provides project direction, engineering, administration, and logistical support. Prime BEEF teams are deployed during peacetime as directed by HQ USAF or Joint Chiefs of Staff (JCS), unit training, disaster recovery or emergency assistance, and project assistance as requested by MAJCOM.

In times of war, teams are deployed as directed by war plans or by Air Force Engineering and Services Center (AFES). Gaining commands may redeploy Prime BEEF forces. Prime BEEF Mobility teams are, as a rule, integrated with base civil engineering squadrons at main operating bases. At limited, standby, and bare bases, teams are normally used to form a base civil engineering function. Prime BEEF teams are deployable worldwide on a 28-hour notice. This 28-hour period includes a 24-hour alert period plus four hours for deployment after the order is received.

**Team Concept.** Along with RED HORSE, Prime BEEF teams help get a base ready for combat air operations, recover from war damage, provide base operation and maintenance support, and give crash rescue and fire suppression support.

*Prime BEEF Contingency Force–1 (CF–1) Team (UTC 4F9CA).* This team is a mobile team which provides for rapid runway repair (RRR). The team will have a total of 20 members from the Structural/Pavements career fields and 1 CE officer. The team is deployable to main, limited, standby, co-located operating, and bare bases and requires base operating support. The team is also supplemented with one CF–2 team for full RRR capability and provides additional support for beddown and bomb damage repair when not engaged in RRR activities. Each member will have individual toolkits plus selected home based heavy equipment.

Each team member gets annual training in RRR. This includes repair techniques on an actual or simulated crater, mat assembly and towing, and how to operate related vehicles. Mobility exercises will be held at least once every 24 months (not less than 18 months and not more than 30 months) depending on the availability of training sites. The "hands on" training includes repairing large pavement craters, explosive ordnance reconnaissance (EOR), and chemical warfare (CW) defense techniques, small pavement crater repair, expedient facility and utility repair techniques, oversea utility systems, and installation of Harvest Eagle equipment.

*Prime BEEF CF–2 Team (UTC 4F9CB).* This team augments a CF–1 team and is also a mobile team. This team has a total of 70 members including 1 Electrician Apprentice (3 level), 2 Specialist (5 level), and 1 Technician (7 level). The team takes care of force beddown, aircraft arresting system installation or relocation, operations and maintenance, bomb damage repair, and natural disaster recovery. This team also requires base operating support.

Team members are issued individual mobility toolkits and equipment. Their personal clothing must conform with the uniform clothing allowance. The team will deploy with a CF–2 team toolkit and may also deploy with the Harvest Eagle kits and contingency support set.

Both CF–2 and CF–2 team members will receive weapons training on the M–16 rifle or .38 caliber revolver. Other areas of training are in military sanitation, government vehicle operation, expedient methods, explosive ordnance reconnaissance (EOR), and chemical warfare (CW) defense, field training, and RRR. CF–2 teams will have mobility training the same frequency as CF–1 teams.

There are numerous other teams used in mobility and contingency operations. You and technicians will not be concerned with these teams. For information on these other teams, you can refer to AFR 93–3, *Air Force Civil Engineering Prime (BEEF) Program—Base Engineering Emergency Force*, Chapter 2.

**Exercises (004):**

1. What role do military personnel assigned to Prime BEEF teams play during peace time nonemergency situations?

2. What significant changes were made to the Prime BEEF concept in the 70's as opposed to the 60's?

3. What were additional requirements placed on the Prime BEEF operation due to the changes of the 70's?

4. What are the two primary responsibilities of Prime BEEF teams?

5. Who provides project direction, engineering, administration, and logistical support for Prime BEEF teams during peace time deployment?

6. Within what time limit must all Prime BEEF teams be deployable on a worldwide basis?

7. What career field are the CF–1 team members from?

8. List the number of interior electrical personnel and their skill level that are assigned to the CF–2 teams.

9. What is each CF–2 team member personally issued in the way of equipment?

10. What weapons are Prime BEEF teams trained on?

**005. State the function of a RED HORSE Squadron and identify the echelons of deployment from a list of tasks.**

**Function of REDHORSE.** Air Force squadrons with the title "RED HORSE" have the ability to repair major damage that is inflicted on a base. RED HORSE means "Rapid Engineer Deployable Heavy Operations Repair Squadrons Engineer." "RED HORSE" is much easier for you to say. The title explains, to a large extent, the function of the RED HORSE unit.

RED HORSE squadrons provide heavy equipment repair and construction of troop facilities when and where the requirements exceed the base CE's capabilities, and when Army or Navy support is not readily available. These squadrons are formed with trained personnel from all major commands (MAJCOMS). The members are given training to make them proficient in all areas of their skills. This training is necessary to meet the high standards required of persons in RED HORSE squadrons. RED HORSE squadrons are capable of rapid deployment and are responsive to the following situations:

*a.* Worldwide requirements as directed by Headquarters USAF.

*b.* USAF tactical forces deployed in conjunction with war or the likely event of war.

*c.* Establishment of new base facilities or the expansion and upgrading of existing base facilties.

*d.* The repair or replacement of damaged or destroyed facilities in combat zones.

*e.* Meeting recovery requirements for Air Force facilities in case of natural disasters.

*f.* Training exercises, maneuvers, and special projects.

RED HORSE also makes major construction alterations and additions to an existing base, as would be the case when a runway is lengthened, a hanger is built, or aircraft parking ramps and taxiways are constructed.

The RED HORSE squadron can move on to an abandoned air base and restore it to the extent necessary for flying operations. Also, the squadron can move into an area where there has never been a base and build one.

**Deployment.** RED HORSE Squadrons are organized into three deployment echelons:

CES–1, an air-transportable squadron made up of 14 people and can be deployed 12 hours after notification. This squadron performs advanced airfield surveys, site layout, and prepares for future development of a base of operations during contingencies.

CES–2, an air-transportable squadron made up of 81 people and can be deployed 72 hours after notification. It can perform heavy bomb damage repair, build shelters, perform limited earthwork and light base development (such as installing aircraft arresting systems, expedient airfield matting and essential utility systems) during the initial phase of contingencies.

CES–3, a surface movement squadron which can deploy in 10 days after notification, and can perform heavy repair, permanent construction, and airfield expansion.

Each echelon has its own separately identified personnel and equipment. Deployment to a bare base is done by CES–1 and CES–2, and is augmented by firefighting or crash rescue teams. A bare base is a base which has as a minimum, a runway, taxiway(s), and parking areas that are adequate for the deployed force, and which has a source of water that can be made potable.

**Exercises (005):**

1. How are RED HORSE Squadrons formed?

2. What services do RED HORSE Squadrons perform?

3. From the list of tasks below performed by RED HORSE Squadrons, designate which echelon performs the task by placing CES–1, CES–2, or CES–3 in the space provided.

a. ____ Field surveys.
b. ____ Rapid runway repair.
c. ____ Install high intensity discharge lighting in a new hangar.
d. ____ Extend an existing runway by 1000 ft.
e. ____ Install an aircraft arresting barrier.
f. ____ Make preparations for future development.

## 1-2. Career Progression

The military services long have recognized that people possess different aptitudes, abilities, and interests. The present airman classification system was adopted shortly after the Air Force became a separate branch of service. It has remained basically unchanged since. The system uses a testing program to identify each airman's aptitude and abilities so that he or she can be assigned to a suitable career field. This system provides a systematic method by which the Air Force insures that each job is filled by well-qualified people. It also affords each person an opportunity to advance within their chosen field according to their abilities. The purpose of the classification system is to identify the duties and tasks to be done in each job, and to identify the individuals who have or can develop the abilities to perform the job.

Jobs in the Air Force are classified into career fields. All similar or related jobs are grouped together to form a career field. At present, there are 47 career fields in which airman can be assigned. Furthermore, each career field is

subdivided into individual jobs or specialities. Each subdivision of a career field is called a career field ladder.

To become better acquainted with your career field, you need specific information. The following objectives provide this information.

**006. Identify AFSC, activities, and responsibilities associated with the steps in an airman mechanical/electrical career ladder.**

**Airman Mechanical/Electrical Career Field Chart.** This chart is a graphic presentation of the 54 career field and is shown in figure 1-2. As you can see, the 54 career field is made up of a number of Air Force specialties. Your specialty, as you well know, is electrician, AFSC 542X0. By observing the chart, you can see just how you fit into the picture. If you are a 3-level electrician, notice that your present position is Apprentice Electrician, AFSC 54230. It is shown just below the position you are working for, AFSC 54250. There are pay grades for each skill level. For example, the pay grade for an electrician is E3, E4, or E5.

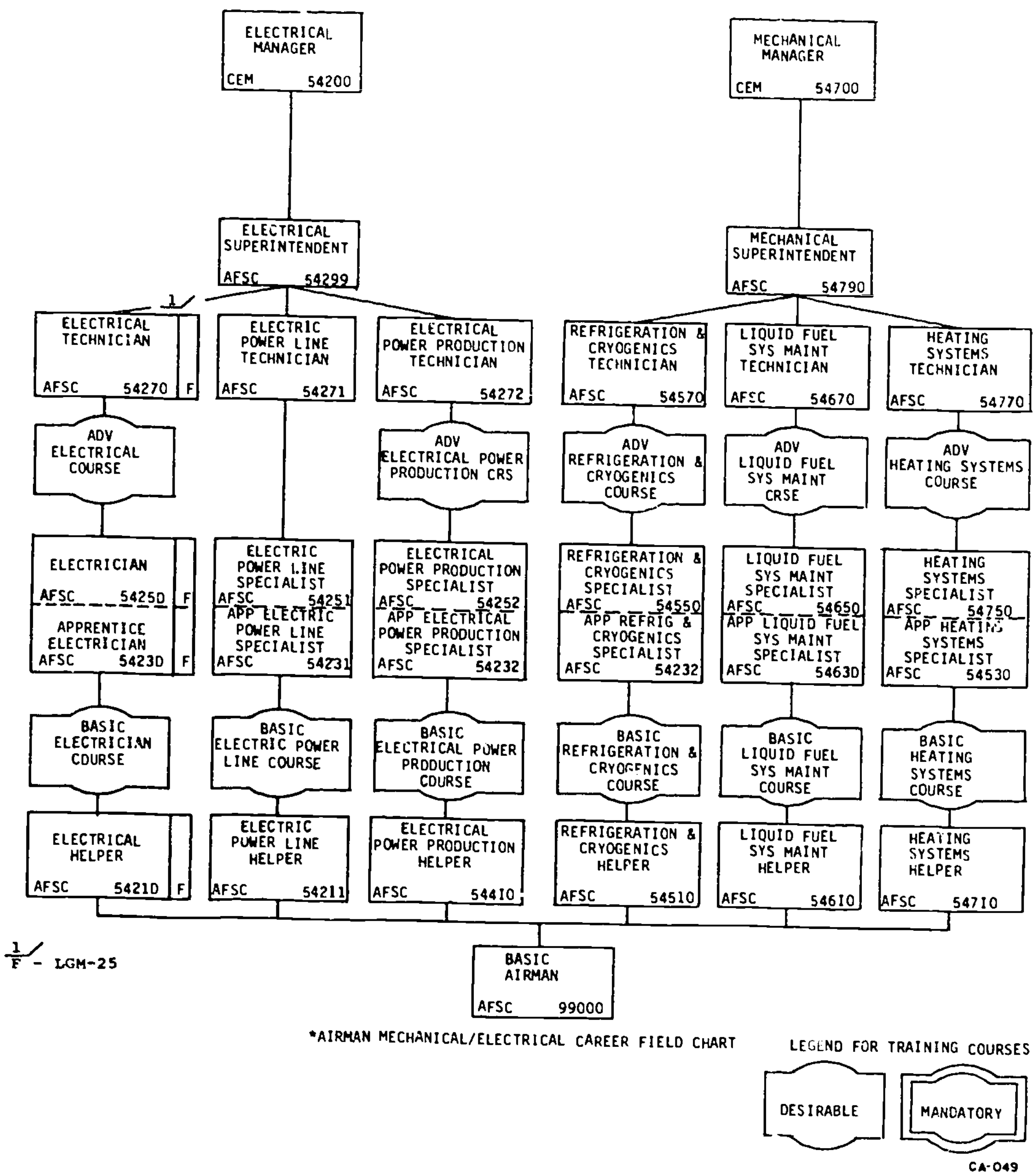


Figure 1-2. Mechanical/Electrical Career Field Chart.

The electrical superintendent, AFSC 54299, above the three electrical specialities, is in charge of the three specialties. The three electrical specialties are electrician, power lineman, and power production. The three electrical specialties feed into the superintendent position. The 54 career field includes other specialties, as shown in the chart. Often you will work closely with people from these shops. A cooperative attitude on your part, as well as the other people, will help to get CE jobs done better and faster.

The electrical manager, AFSC 54200, the next position above the electrical superintendent, is an E9, Chief Master Sergeant. This position is known as the Chief Enlisted Manager (CEM). Only a Chief can hold this position. This person has had extensive experience and training, a high managerial ability to plan, direct, coordinate, implement, and control a wide range of work activities in the electrical specialties.

**Exercises (006):**

1. What is the AFSC of each step up the career field ladder from basic airman to manager in your career field? Use figure 1-2.

| *TITLE* | *AFSC* |
|---|---|
| a. Basic airman. | |
| b. Electrical helper. | |
| c. Apprentice electrician. | |
| d. Electrician. | |
| e. Electrical Technician. | |
| f. Electric Superintendent. | |
| g. Electric Manager. | |

2. If you were a 5-level electrician, what is the highest grade you can hold?

3. Your electrical superintendent is from one of what three specialties?

4. What is the electrical manager's main responsibilities?

**007. Select the duties and responsibilities that belong to the specialist level electrician.**

**Duties and Responsibilities of an Electrician.** You must know what your duties and responsibilities are if you are to do your job well. Ability is important and needed, but if you do not know what the job requires, you have trouble in making full use of your abilities. Your duties and responsibilities are found in AFR 39-1, *Airman Classification Regulation*. Your specialty description, AFSC 54250, along with the Electrical Technician, AFSC 54270, and Electrical Superintendent, AFSC 54299 has been reproduced here for your convenience and study. Refer to figures 1-3, 1-4, and 1-5.

In figure 1-3, you can see the specialty description you are studying and working toward. Note that it is broken down into four main sections. These are (1) specialty summary, (2) duties and responsibilities, (3) specialty qualifications, and (4) specialty data. Each of these sections has information of value but the most important to you are the "duties and responsibilities" and "specialty qualification." You can see from your specialty description that you do quite a lot of maintenance and repair work and a little supervision. You are expected to perform maintenance work and as you gain in experience and knowledge you will be put in charge of work crews. As you progress up your ladder, you will be doing more supervisory type work. The added supervisory requirements separate the specialist from the apprentice and forms the basis for advancement to the technician position. Study the three specialty descriptions for your career field in this text and know the differences in their requirements. Use the knowledge you have gained here to help you progress in your specialty.

**Exercises (007):**

1. Place an "X" in the space provided beside the duties performed by a specialist level electrician.

____ a Connects and utilizes test equipment and meters for locating malfunctions.
____ b. Cuts, threads, and bends conduit.
____ c. Solves complex installation and repair problems by studying wiring diagrams.
____ d. Pulls conductors into conduits and raceways.
____ e. Directs electrical maintenance activities.
____ f. Determines procedures for maintenance and modifications of installed equipment.
____ g. Cleans, repairs, and replaces armature and field windings.
____ h. Replaces defective ballasts.
____ i. Reviews repairs to insure compliance with National Electric Code.
____ j. Develops organizational structure to define lines of authority.

## 1-3. Communications Security (COMSEC)

Like safety, security is a topic that applies to each of us all the time. The word "security," of course, refers to the protection of Air Force information and materials. This protection is designed to provide for the Air Force the freedom and secrecy of actions needed to do our part in the national defense.

The fact that you don't handle items marked "classified" doesn't mean you are exempt from taking part in the security program. In fact, those who seldom work in, or with, a security atmosphere, may well be the most vulnerable to another nation's collection of facts related to Air Force operations.

The United States must protect against hostile, destructive, or subversive action. To do this, certain official information affecting the national security must be

AFSC 54250*
Semiskilled AFSC 54230*
Helper AFSC 54210*

AIRMAN AIR FORCE SPECIALTY

## ELECTRICIAN

### 1. SPECIALTY SUMMARY

Installs, services, troubleshoots, and repairs low voltage electrical and electronic equipment and systems associated with generation, interior distribution, and control.

### 2. DUTIES AND RESPONSIBILITIES

a. *Installs, services, modifies, and repairs electrical equipment and systems.* Inspects, troubleshoots, services, assembles, installs, connects, repairs, adjusts, and tests low voltage electrical generation, distribution, control, and utilization equipment and systems. Examines electrical equipment and systems for damages, corrosion, and operation. Connects and utilizes test equipment and meters, such as voltmeters, ammeters, megohmeters, and oscillographs for locating equipment, distribution, and control systems malfunctions and faults. Cleans and adjusts relay timing mechanism and contacts, rotating machinery brushes, circuit breaker and disconnect contacts, and control sensing mechanisms. Repairs and services isolated de-energized high voltage equipment (rotating machinery, circuit breakers, and associated high voltage interior power systems), although 600 volts is normal dividing line between high and low voltage systems, under direct supervision and guidance. Cuts, threads, and bends conduit. Assembles and replaces conduit, conduit fittings, junction boxes, and supports. Pulls conductors into conduits and raceways. Splices conductors. Installs and connects distribution, generation, and utilization equipment components, such as control sensing devices, relays, switches, panel boards, transformers, voltage regulators, battery chargers, motor speed controllers, motors, receptacles, lighting fixtures, heating elements, battery banks, generators, circuit breakers, surge protection, ground rods, lighting air terminals and ground lamps. Installs, tests, and maintains power sources for cathodic protection systems. Uses common hand tools, tubing and conduit benders, hand and motor operated conduit threading machines, soldering irons, and hand drills.

b. *Troubleshoots and repairs electrical and electronic circuits and equipment.* Repairs and replaces defective insulated conductors and grounding systems. Cleans, repairs, and replaces armature and field windings. Refaces commutators and slip rings. Replaces defective lamps, lighting fixtures, ballasts, and starters. Installs, maintains, troubleshoots, and repairs explosion proof lighting and wiring systems, and solid state electronic equipment such as motor controlers switch gears, power supplies, lighting control systems, and electronic alarm system components. Troubleshoots complex electrical control circuits and replaces defective components. Performs testing, installation, and repair tasks such as testing and calibrating electric power systems relays and meters, and troubleshooting equipment control circuits; installs, repairs, and adjusts electrically operated circuit breakers. Replaces defective components in power rectifiers, photoelectric sensors, and voltage and current regulators. Adjusts and repairs electronic solid-state devices and circuits. Tests and repairs intrusion and ultrasonic alarm systems.

c. *Supervises electrician personnel.* Assigns work and reviews completed repairs to insure compliance with National Electrical Code, safety codes and instructions, and applicable technical publications. Instructs subordinates in techniques and procedures of installation, inspection, maintenance, and repair of interior distribution system. Evaluates work performed and keeps immediate supervisor informed on job status.

### 3. SPECIALTY QUALIFICATIONS

a. *Knowledge.* Knowledge of principles of electricity to include compoutations and measurement of common properties (resistance, inductance, capacitance, electrical potential, and current flow); magnetism; electric circuit analysis; rotating machinery operation and control; industrial electronics (operation and elements of rectifiers, voltage regulators, and photoelectric and amplifier circuits); transformer operations and connections; electric equipment control circuits (servomechanism, temperature sensing devices, types and functions of relays); lightning and system grounding systems and equipment (lightning arrestors, shielding means, power and utilization equipment grounding schemes); cathodic protection; reading and interpretation of electric schematic and one-line diagrams; construction and assembly of printed circuit boards, transistors, capacitors, and diodes; operation of solid state test equipment; electronic soldering techniques; safety rules and practices; rescue and resuscitation of electric shock victims; operation of test instruments; and use of hand and power tools used in installation and repair of electric equipment and systems is mandatory. Possession of mandatory knowledge will be determined according to AFR 35-1.

b. *Education.* Completion of high school with courses in physics and mathematics is desirable.

c. *Experience.* Experience in functions such as installation, repair, and servicing of electrical generation, distribution, and utilization equipment and systems is mandatory.

d. *Training.* Completion of a basic electrician course is desirable.

e. *Other.*

(1) A minimum aptitude level of Electronic 50 is mandatory.

(2) Normal color vision as defined in AFR 160-43 is mandatory.

* (3) Physical qualification for military drivers according to AFR 160-43 is mandatory for entry into this AFSC.

### * 4. SPECIALTY DATA

a. *Grade Spread:*

| | |
|---|---|
| E-3 through E-5 | 54250 |
| E-3 | 54230 |

b. *Related D.O.T. Jobs:*

| | |
|---|---|
| Electrician | 824.261-010 |
| Electrician Helper | 829.684-022 |

c. *Related DOD Occupational Subgroup:* 721

### 5. *SPECIALTY SHREDOUTS

| *Suffix* | *Portion of AFS to Which Related* |
|---|---|
| F | LGM-25 |

Figure 1-3. Electrician.

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AIRMAN AIR FORCE SPECIALTY

ELECTRICAL TECHNICIAN

## 1. SPECIALTY SUMMARY

Inspects, installs, services, troubleshoots, repairs, and modifies low voltage electrical and electronic equipment and systems associated with the generation, distribution, utilization, and control systems; and supervises electrical activities.

## 2. DUTIES AND RESPONSIBILITIES

a. *Advises on technical problems of installation, modification, and repair of electrical real property installed equipment and systems.* Solves complex installation, control, modification, and repair problems by studying wiring and schematic diagrams and technical publications; and determining capability, capacity, and limitations of equipment, tools, and materials. Determines procedures for maintenance, installation, modification, and repair of electrical real property installed equipment and systems. Recommends revised maintenance, repair, and installation procedures to facilitate full utilization of personnel and equipment. Diagnoses recurring malfunctions and recommends corrective action, proposed modifications, or other appropriate means.

b. *Installs, services, modifies, and repairs electrical and electronic equipment and systems.* Performs difficult tasks involving inspection, troubleshooting, servicing, assembly, installation, connecting, adjusting, and testing of all electrical generation, distribution, control, and utilization equipment and systems rated 600 volts or less, such as fire and gas detection and warning systems, security systems, equipment control systems, system protective devices, explosion-proof lighting and wiring systems, high-bay and industrial shoplighting systems, security lighting, electric heating and cooking systems, electrical ground detection systems, station batteries and charging systems, generators and excitors, motors and starters, and power protective relaying systems. Performs complex testing, installation, and repair tasks, such as testing and calibrating electric power systems relays and meters, troubleshooting equipment control circuits, laying out and installation of complex conduit and wiring systems, and repair and adjustment of electrically operated circuit breakers. Installs, repairs, maintains, troubleshoots, and tests solid state electronic equipment such as motor controllers, switch gears, power supplies, lighting control systems, and electronic alarm system components. Installs, tests, and maintains electric power sources for cathodic protection systems. Installs, services, and repairs, although 600 volts is normal voltage limit, isolated, de-energized high voltage equipment associated with power generation and interior distribution systems.

c. *Inspects electrical systems and equipment.* Inspects completed or in-progress work to insure compliance with standing operating procedures, safety standards, and technical publications. Performs periodic inspections to determine safety and operational condition of electric power and control systems. Detects potential malfunctions by examining for loose connections; improper insulation; overheating of electrical systems components; and undesirable collections of dirt, grease, moisture, and corrosion on electrical equipment wiring and inclosures. Interprets inspection findings, and determines adequacy of corrective action.

d. *Supervises electrical personnel.* Plans and schedules work assignments. Establishes work methods, production controls, and performance standards for subordinates. Insures availability of required maintenance equipment, tools, test instruments, and space parts. Evaluates performance of subordinates performing installation, repair, servicing, and test functions in terms of compliance with policies, directives, and technical manuals and orders. Conducts on-the-job training of electrical personnel in installation, servicing, test, and repair of interior electrical distribution and utilization equipment and control systems.

## 3. SPECIALTY QUALIFICATIONS

a. *Knowledge.* Knowledge of principles of electricity to include computation and measurement of common properties (resistance, inductance, capacitance, electric potential, and current flow); magnetism; electric circuit analysis; rotating machinery operation and control; repair, servicing, and installation of high voltage equipment; industrial electronics (operation and elements of rectifiers, voltage regulators, photoelectric and amplifier circuits); construction and assembly of printed circuit boards, transistors, capacitors, and diodes; operation of solid state test equipment; electronic soldering techniques; motor control, circuits, and protective devices (synchronous and induction motor controllers, overcurrent and overvoltage protection); transformer operations and connections; electrical equipment control circuits (servomechanisms, temperature sensing devices, types and functions of relays); lightning and system grounding systems and equipment (lightning arrestors, shielding means, power and utilization equipment grounding schemes); cathodic protection, reading and interpretation of electric schematic and one-line diagrams; safety rules and practices; rescue and resuscitation of electric shock victims; operation of test instruments, and use of hand power tools used in the installation and repair of electric equipment and systems in mandatory. Possession of mandatory knowledge will be determined in accordance with AFR 35 1

b. *Education.* Completion of high school with courses in physics and mathematics is desirable.

c. *Experience.* Qualification as an Electrician is mandatory. In addition, experience in performing or supervising functions such as the installation, maintenance, troubleshooting, and repair of electrical distribution and utilization equipment and systems is mandatory.

d. *Training*

(1) Completion of an advanced electrician course is desirable.

(2) Completion of appropriate base level management course is desirable.

e. *Other.* Normal color vision as defined in AFR 160-43 is mandatory.

## 4. SPECIALTY DATA

a. *Grade Spread.* Staff sergeant through master sergeant.

b. *Related D.O.T. Job*

Electrician Foreman . . . . . . . . . 829.131

c. *Related DOD Occupational Subgroup* 721

## 5. *SPECIALTY SHREDOUTS

| *Suffix* | *Portion of AFS to Which Related* |
|---|---|
| F . . . . . . . . . . . . . . . . . . . . . . . . | LGM 25 |

Figure 1-4. Electrical technician.

AFSC 54299
• (CEM Code 54200)

AIRMAN AIR FORCE SPECIALTY

ELECTRICAL SUPERINTENDENT

## 1. SPECIALTY SUMMARY

Superintends activities engaged in construction, installation, modification, operation, maintenance, repair, and overhaul of interior, exterior, electrical power generating and control systems; fire alarm, intrusion and control systems; cathodic protection systems; rotating and static uninterruptible power systems (UPS); aircraft arresting systems; and electrical distribution and equipment.

## 2. DUTIES AND RESPONSIBILITIES

a. *Plans and organizes electrical activities.* Supervises, plans, and schedules work and training assignments. Establishes performance standards and work procedures to insure effective personnel utilization and to increase efficiency and economy of operation. Provides for and controls use of equipment, space, and supplies. Develops organizational structure to define lines of authority and assigns specific responsibilities. Programs and coordinates electrical distribution and system outages, maintenance, and repair requirements with related activities and users.

b. *Directs electrical activities.* Supervises work accomplishment in electrical power production and aircraft arrest-barrier activities by assigning personnel to specific functions such as installation, modification, operation, maintenance, repair and overhaul of equipment. Included are gas and diesel engines, gas turbines, steam generators, and rotating and static UPS; and associated electric power generating equipment to include controlling, regulating, recording and monitoring primary plant equipment and aircraft arresting systems. Directs utility electrical power construction, installation, operation, maintenance and repair activities to include high voltage work; airfield and approved lighting systems; overhead and underground distribution systems; fire alarm, intrusion and control systems; cathodic protection systems; interior electrical work; and electrical support of missile weapon systems. Establishes teams or shifts. Identifies and controls requisitioning parts, systems, fuels, lubricants, bench stock and technical publications. Insures compliance with safety practices and regulations. Analyzes productivity and work quality. Monitors electrical generating unit records and analyzes for organization, intermediate or depot level maintenance; and preparation of maintenance forms, reports and records. Issues and logs safe clearance procedures for all crafts engaged in maintenance of electrical systems and/or equipment.

c. *Establishes and conducts on-the-job training for electrical personnel.* Directs on-the-job training and monitors progress of personnel. Plans and conducts conferences and classes for instructing personnel on new projects, work requirements, and equipment. Arranges for attendance of selected individuals at formal and special training courses.

d. *Inspects and evaluates electrical activities.* Performs periodic and special inspections of electrical activities to insure compliance with policies, regulations, and technical publications; and to provide assistance in solving maintenance, supply, and personnel problems. Interprets inspection findings and initiates corrective action. Obtains certification of power line crew for performance of work on energized systems; and certification of power production personnel in power plant, UPS and standby generator operation. Insures adequacy of maintenance performed on power systems. Obtains special tools and equipment required for safe performance of tasks assigned.

e. *Performs technical electrical functions.* Resolves technical problems and interprets manuals and technical publications applicable to construction, installation, modification, operation, maintenance, repair, and overhaul of electrical power generating systems and aircraft arresting systems. Isolates unusual malfunctions; examines faulty components and material; and determines need for repair, replacement, and/or need for submitting material deficiency and unsatisfactory reports under Air Force regulations. Evaluates operational effectiveness of electrical systems and recommends engineering studies examining modification of equipment and materials.

## 3. SPECIALTY QUALIFICATIONS

a. *Knowledge:*

(1) Knowledge of the principles of electricity, electrical circuitry and distribution, internal combustion engines and other prime movers for electrical generating systems or units; characteristics, capabilities, and applications of electrical generation and distribution equipment and material such as engines, generators, rotating and static UPS; solid state components, wire conduit, motors, transformers, regulators, solenoids, circuit breakers, switches, control systems, relays and fuses; procedures for repair of high voltage circuitry and equipment; balancing of loads; installation operation and maintenance of aircraft arresting systems; fire alarm, intrusion and control systems; cathodic protection systems; and safety rules and practices is mandatory.

(2) Knowledge of field expedient construction, maintenance, and operation, including field sanitation, first aid, and work parties, is desirable.

b. *Education.* Completion of high school with courses in physics and chemistry is desirable.

c. *Experience.* Qualification as an Electrical Technician, Electrical Power Line Technician, or Electrical Power Production Technician is mandatory. In addition, experience in directing functions such as inspection, operation, maintenance, and repair of interior, exterior, and electrical power generating equipment and systems; rotating and static UPS, and aircraft arresting systems is mandatory.

• d. *Training.* Not applicable.

e. *Other.* Normal color vision as defined in AFR 160-43 is mandatory.

## • 4. SPECIALTY DATA

a. *Grade Spread:*

| | |
|---|---|
| E-7, E-8 | AFSC 54299 |
| E-9 | CEM Code 54200 |

b. *Related D.O.T. Jobs:*

| | |
|---|---|
| Electrician Supervisor | 829.131-014 |
| Diesel-Powerplant Supervisor | 631.131-010 |
| Line Foreman (Light, Heat, and Power) | 821.261-018 |
| Substation Operator, Chief | 952.131-010 |
| Substation Operator, Generation | 952.362-026 |

c. *Related DOD Occupational Subgroup:* 721

Figure 1-5. Electrical superintendent.

protected. This is done to keep unauthorized persons or agencies from obtaining it. At the same time, U.S. citizens must be kept informed of the activities of their Government. Therefore, information may be withheld only when necessary in the national interest, and it must be removed from any security system as soon as that protection is no longer warranted.

Using the telephone to discuss classified information is strictly forbidden by AFR 205-1, *Information Security Program (Supplements DOD 5200.1-R)*. Using any other insecure method to discuss classified information is also forbidden. Discussion of classified information with insecure communications, however, is not the problem. The problem is that your unclassified telephone conversations with your friends and seemingly unrelated, unclassified telephone conversations made by other base personnel can provide an enemy agent bits and pieces of information. Here, we examine COMSEC and its importance to the protection of classified information. Our intent is to help you gain the knowledge you need in protecting classified information. Additionally, this text helps you satisfy some of the training needs identified in the communications security education program (CSEP).

**008. State the individual's responsibilities in the information security program, and list the minimum security orientation requirements.**

**Individual Responsibilities.** Security is the sum total of each individual's adherence to and compliance with sound protective practices. Adequate security can be obtained only by sound direction from supervisors, coupled with alert performance of duty by each member of the Air Force. You are responsible for familiarizing yourself with, and adhering to (a) the provisions of the regulations and supplementary instructions which apply to your assigned duties, (b) protecting and accounting for all classified information you know or possess, regardless of how you obtained it, and (c) making sure that any document you sign or that any instruction you give does not require, authorize, or imply an action in violation of information security policies.

**Security Orientation.** The details of each command or office security orientation program must be designed to satisfy the requirements of the mission and functions of the organization or office. The content of the program must also be varied according to the duties and responsibilities of different groups of people. This briefing must cover the elements listed in DOD 5200.1-R, *Information Security Program*. (This DOD regulation is supplemented by AFR 205-1.) Minimum requirements of such a briefing are as follows:

*a*. All persons whose duties require them to have access to classified information must understand the purpose and principles of the information security program and their personal responsibility for protecting all classified information they know or possess.

*b*. All persons whose duties include responsibility for initiating, classifying, declassifying, using, or handling classified material, or initiating plans, programs, project, or instructions wherein the security of classified information is a factor or might be affected, must be informed of the specific requirement of the regulations and supplemental instructions that apply to them in the performance of those duties.

*c*. All individuals who exercise supervision over personnel are responsible for assuring their adherence to the instructions which apply to them.

*d*. Supervisory personnel should conduct this orientation and training as an integral part of their assigned responsibilities.

**Exercises (008):**

1. What are your personal responsibilities under the information security program?

2. What are the minimum requirements, presented in a security orientation briefing?

**009. Identify information of intelligence value.**

**Information of Intelligence Value.** Information of intelligence value includes both classified and unclassified information. Classified information is official information that must be protected from disclosure in the interest of National Defense. Unclassified information is official information that may be harmless when considered bit by bit, but can be of intelligence value when compiled.

*Classified information*. Within the Federal Government there is some official information and material which, because it bears directly on the effectiveness of our foreign relations, must be subject to some constraints for the security of our Nation and the safety of our people and our allies. To protect against both overt (obvious) and covert (hidden) actions hostile to the United States, it is thus essential that such official information and material be given only limited dissemination. Official information or material that requires protection against unauthorized disclosure in the interest of national security is classified in one of three categories; namely, *Top Secret*, *Secret*, or *Confidential*. You'll learn more about these categories shortly. This classification depends upon the degree of its significance to national security. No other categories are used to identify official information or material that requires protection in the interest of national security, *except* as otherwise specifically provided by Federal statutes.

*Unclassified information*. Unclassified information is official information which may be harmless when considered bit by bit, but can be of intelligence value when compiled. Unclassified information of intelligence value includes information that is in direct support of, or is otherwise directly associated with, classified information and which contributes to knowledge of the classified

aspects of information. This category also includes unclassified information which, when associated with other unclassified information, reveals an insight into, or aspects of, classified information.

There is some information that will not fit into any of the categories of classified information but for one reason or another should be withheld from general public disclosure. This type of information is designated as "For Official Use Only." Some examples of For Official Use Only material are:

*a*. Reports of proceedings to select personnel for assignments, school, promotion, retention, and similar purposes.

*b*. Lists identifying firms or individuals suspected under procurement regulations when the lists are compiled in connection with investigation of irregularities.

*c*. Inspector general reports, auditor general reports, or other reports of inspections, investigations, or surveys that pertain to safety or the internal management, administration, and operation of the Air Force, unless they reflect on classified programs.

**Exercises (009):**

1. If one of the following statements is correct, write true in the space provided and correct the false statements.

____ a. Information of intelligence value includes classified and unclassified official information.

____ b. One purpose for classifying information is its probable impact on the international relations of the United States.

____ c. Official information which needs protection in the interest of our Nation's defense is usually unclassified.

____ d. Unclassified information is official information such as the base telephone directory.

____ e. Information or material which does not meet the need for security classification but is not intended for general release is considered Secret.

____ f. According to the material in this text, generally all forms of official information can be of intelligence value.

**010. Define the security classification categories and identify them with examples of types of information.**

**Classification Categories.** As stated previously, in protecting our national security, three classification categories are authorized: Top Secret, Secret, and Confidential. They are used in the following manner.

*Top Secret*. This classification applies to national security information or material which requires the highest degree of protection. The unauthorized disclosure of Top Secret information could reasonably be expected to cause *exceptionally grave damage* to the national security. A few examples of possible consequences that could result if Top Secret material were disclosed to unauthorized persons are (a) a definite break in diplomatic relations affecting the defense of the United States, (b) an armed attack against the United States or its allies, (c) a war, or (d) the compromise of military or defense plans, intelligence operations, or scientific or technological developments vital to the national defense. Examples of types of information originally assigned to the Top Secret Category by Air Force personnel are listed below.

*a*. Strategic Plans documenting the overall conduct of a war.

*b*. War planning documents with time phasings, specific dates, or D-dates, that contain worldwide planning data and assumptions.

*c*. An operations plan, either for a single operation or a series of conducted operations, containing any of the factors above, and with sortie rates or target data.

*d*. Documents containing any of the considerations above directly related to a Top Secret war planning document which, if by itself were revealed to unauthorized parties, could result in actual compromise of a particular Top Secret plan.

*e*. Intelligence documents that contain completed intelligence of such scope that it reveals a major intelligence producing effort on the part of the United States.

*f*. Plans or policies for conducting intelligence or other special operations.

*g*. Critical information concerning radically new and extremely important equipment; for instance, nuclear weapons, atomic weapons stockpile data, and any other munitions of equal importance and vital in every aspect to the national defense. Even at first glance you can easily understand why documents concerning the foregoing topics must be given the greatest protection.

*h*. Communications security devices and cryptomaterial that would permit decoding of a Top Secret transmission, or that would permit, through cryptanalysis, the solution of a cryptosystem used to transmit Top Secret information.

*Secret*. This classification applies to that national security information or material that requires a substantial degree of protection. The unauthorized disclosure of Secret items could reasonably be expected to cause *serious damage* to the national security. Improper disclosure of Secret information could jeopardize the international relations of the United States, endanger the effectiveness of a national defense policy, compromise important military defense plans, including scientific or technological developments, or reveal important intelligence operations. The difference in Secret and Top Secret is entirely a matter of degree, as illustrated by the following examples of Secret information:

*a*. Defense or other military plans, not included under Top Secret, including certain development and procurement plans and programs, but not necessarily including all emergency plans.

*b*. Specific information which, standing alone, reveals the military capabilities or state of preparedness of the Air Force, but not including information which if disclosed to unauthorized parties could result in compromise of a Top Secret plan.

**Confidential.** This classification applies to national security information or material that requires protection. The unauthorized disclosure of Confidential materials could reasonably be expected to cause identifiable *damage* to the national security. The difference in Secret and Confidential is also a matter of degree. The following examples illustrate this point.

*a*. Defense or other military plans of lesser importance than Secret.

*b*. Specific information that reveals security plans or programs, but not including those that could result in compromise of higher classified plans.

**Exercises (010):**

1. Define Top Secret information.

2. Define Secret information.

3. Define Confidential information.

4. Match the column A examples with the most appropriate security category in column B by writing the column B alpha in the space provided. Column B items may be used once or more than once.

| *Column A* | *Column B* |
|---|---|
| _____ (1) Information that reveals the state of readiness of the Air Force. | a. Top Secret. |
| _____ (2) Information that reveals minor military plans. | b. Secret. |
| _____ (3) A plan for conducting intelligence operations. | c. Confidential. |
| _____ (4) Information concerning nuclear weapons. | |
| _____ (5) Information that reveals the capabilities of the Air Force. | |

## 011. Given hypothetical situations, determine if the security precautions adhere to accepted guidelines for COMSEC.

**Precautions.** A very important part of our security program is COMSEC. It is designed to deny to unauthorized persons information of intelligence value which could be obtained by the possession and study of USAF telecommunications. Telecommunications are any transmission, emission, or reception of signs, signals, writing, images, sounds, or information of any nature by wire, radio, visual, or other electromagnetic system. Telecommunications are also sometimes referred to as "electrical communications," or more simply "communications."

**Need.** Why do we need COMSEC? The answer is simple: to prevent unauthorized persons from intercepting our communications, studying them, and extracting any information of intelligence value. It is suspected that practically every major nation in the world today is making an effort to collect intelligence from the unclassified communications of the nations they oppose politically, economically, and militarily. They probably make this effort because unclassified communications, as we illustrate shortly, when collected and analyzed for intelligence content, can reveal details concerning an opponent's activities. For instance, operations, plans, programs, strengths, weaknesses, numbers, equipment, deployments, capabilities, intentions, and just about everything else can be obtained through communications monitoring.

**Problem.** The major problem facing the USAF today, with respect to communications security, is the fact that thousands of Air Force people must use unprotected communications systems to do their jobs. Very often, our jobs require involvement with classified activities or support of classified activities. Experience has shown that a study of numerous unclassified communications contacts, such as telephone calls about classified projects, can reveal certain details about those projects. Some examples follow.

*Communication #1*. The NCOIC of a fighter group operations office in the United States makes a telephone call to a distant supply activity. He or she inquiries about the procedures for obtaining 100 copies of the air navigation maps for an area in the Middle East. The supply activity tells him or her to submit a form and that he or she will receive the maps within 3 weeks. The NCOIC says, "That will be fine," and hangs up.

*Communication #2*. An airman assigned to the engine maintenance activity of the same fighter group makes a telephone call the next day to a friend at a distant Air Force base. He or she tells him or her that he or she will be unable to take leave as originally planned, because all leaves have been canceled. The or she reason, he says, is that the workload is too heavy and will be for some time to come.

*Communication #3*. A medical officer assigned to the same fighter group calls a fellow doctor at Wilford Hall Medical Center in San Antonio, Texas. After mentioning that she recalls that her friend had, years ago, been stationed at Dhahran Air Base, Saudi Arabia, she asks him about certain diseases which are common to that area and for a list of reference books on these diseases. Her friend is surprised at her interest in these things, and asks. "How come?" The medical officer replies that she might be able to use the information sometime.

*Communication #4*. A security policeman assigned to the fighter wing, using his base telephone, calls another security policeman during the night. During the conversation, the first security policeman remarks that it is very dull and quiet "around here." The other security policeman states that "in about a month you won't be making that complaint— you could find things quite exciting."

*Communication #5*. A staff officer of the fighter wing makes a radio telephone call to Japan to contact the Wing Operations officer. (This call, made from his desk, is

connected to radio equipment on his base that beams the call, via high-frequency radio energy, to a base in Japan. At that point, another connection to normal telephone circuitry completes the radio telephone connection.) The staff officer has considerable difficulty finding Colonel Smith. In the process of reaching him, he has to explain that Colonel Smith is the 82nd Fighter Wing operations officer, currently TDY to the Pacific, and is visiting Colonel Jones, the Director of Intelligence. When he finally reaches Colonel Smith, he tells him that the Wing Commander wants him to cut his TDY short and to get back home quickly. When Colonel Smith asks why, the staff officer says "Something big has come up, we are plenty busy, and I can't say much more than that you are needed and quickly."

*a.* Each of the fictitious communications above is unclassified. No one violated security. In each example, the people communicating had no idea that the other conversations had taken place. And yet, we can see from examining all of the conversations together that each call contains bits and pieces of story— a story that to enemy intelligence analysts would probably be reported to their superiors along the following lines:

FROM COMMUNICATIONS INTELLIGENCE INTERCEPT OF THE 82ND FIGHTER WING TELEPHONE AND POINT-TO-POINT COMMUNICATIONS, IT APPEARS PROBABLE THAT THIS WING HAS BEEN ALERTED FOR DEPLOYMENT TO THE MIDDLE EAST AREA WITHIN THE NEXT 30 TO 45 DAYS. INTERCEPT ACTIVITIES CONTINUING. FURTHER DETAILS WILL BE REPORTED AS DEVELOPED.

*b.* Far fetched? Not at all. Air Force security service communications security surveillance teams, who monitor USAF communications facilities from time to time, have proven conclusively that it is possible to develop such information if you are able to get access to these communications.

*c.* Access to our communications is a simple matter if one has the proper equipment. Telephone calls, for example, can be tapped in so many ways that the people using the telephone cannot detect the presence of a tap. The conversations can be recorded and studied later by an intelligence analyst.

*d.* Automatic voice network (AUTOVON) calls are even easier to intercept, because these long distance calls are usually transmitted by radio beams between towers about 25 miles apart. Anyone with the proper receiver can intercept them. Radio communications are even simpler to intercept. The intercepters need only the right receiver, and to be in a location where they can receive the radio signal.

**Exercises (011):**

1. Homestead AFB is the headquarters for a Top Secret unit deployment. The classified code word for the project is SKYWAY. The unclassified code word is Blue Knight. In each of the situations below, determine if proper COMSEC measures have been used. If incorrect procedures were used, state what the correct procedures are.

*a.* Sgt Jones, NCOIC of the deployment, picks up his office phone and calls Hickman AFB by AUTOVON. Sgt Jones asks Sgt Smith, in Hawaii, if the rosters for Blue Knight are ready and when they will be sent to him. Sgt Smith is not familiar with Blue Knight, so Sgt Jones tells her it concerns having a bunch of people ready to move very soon.

*b.* Major Johnson, project officer for the deployment at Homestead AFB, sends an encrypted classified message to all bases involved in project SKYWAY, requesting that each base alert 100 men and women for deployment to an unknown location within 6 hours.

*c.* Sgt Brown is in a hurry to get some information concerning SKYWAY. He calls Randolph AFB and asks that the information listed in Major Johnson's request of 2 days ago, be sent to him by encrypted message within 1 hour.

*d* Sgt Adams sends a routine message to all bases involved in SKYWAY which reads in part: all Blue Knight actions are delayed 1 day, i.e., exactly 24 hours.

**012. Name the common violations that may occur while using the telephone.**

**Telephone Off the Hook.** Do not discuss classified or unclassified information of intelligence value, or permit it to be discussed in the vicinity of a telephone which is "off the hook." Conversations near an in-use telephone can be picked up and transmitted about as readily as the conversation of the person talking into the telephone.

**Unplanned Conversations.** The greatest problem of the telephone system is the people who use it. For example, during a telephone conversation, have you ever said, "Oh, by the way?" These words usually precede a bit of information you did not intend to discuss when you first picked up the telephone. This practice of not planning telephone conversations frequently leads from discussing unclassified information of no intelligence value to discussing information of intelligence value, *and, at times, even further.*

**Attempting To Disguise Information.** Some people who try to fool anyone who might be listening in on a telephone conversation may do so by attempting to disguise or conceal the meaning of what they are saying. Some of these attempts are cleverly developed; some are very crude; none are successful. This practice is commonly known as talking around. There are two methods of talking around commonly used. These are paraphrasing and comparing

with similar subjects. An example of paraphrasing is "I cannot tell you who the VIP is, but he is the Vice President's boss." Even though it may sound like a riddle, it is a bit of paraphrasing that was used in an actual conversation. In this example, the wording was changed without changing the meaning. Who is the Vice President's boss? He is, of course, the President. You can see that paraphrasing is changing the wording without changing the meaning of a subject. An example of comparing with similar subjects is: "Next year we are going to be flying the same model that you have at Lackland AFB." You may think that this statement is paraphrasing; however, notice the added attempt at deception: comparing with similar subjects. If you know what type of aircraft they have at any air base, the information is not successfully concealed or disguised.

**Homemade Codes or Ciphers.** Another disguise that many people make in an attempt to conceal the meaning of information of intelligence value is their own code. These homemade codes or reference systems are never effective and should never be used in place of authorized codes, ciphers, or secure communications systems. It is easy for an experienced cryptanalyst to decipher any homemade code system.

Remember, the "third man" is listening. He represents an enemy engaged in obtaining intelligence information from USAF electrical communications.

**Exercises (012):**

1. What are the most predominant security violations associated with the use of the telephone?

2. What form of security error is committed by the telephone user who offhandedly interjects additional thoughts about a classified project into the telephone conversation?

3. In what manner do people try to talk around classified information?

## 1-4. Operations Security (OPEC)

From the previous text, you already know that classified information must be safeguarded by every means available. Also, you learned specific facts concerning the security of communications systems used by the Air Force. Undoubtedly you can recall the series of unclassified conversations that were used as an illustration. But these programs do not fully satisfy our needs for protecting USAF information.

All information about an Air Force operation also needs protection because such information is valuable to our enemies. This protection is provided under the Air Force OPSEC program. OPSEC is an overall security program relating to mission accomplishment. It is concerned with the information, actions, and activities that are sensitive in the sense that they can telepgraph our punch to the enemy—they can give advance warning.

In this section, we discuss the Air Force OPSEC program. It is applicable to all peacetime and wartime missions whether operational or supporting. Every Air Force member has a responsibility to maintain operational effectiveness at the highest possible level. This responsibility includes an obligation to apply OPSEC principles and procedures in promoting overall security without detracting from operational effectiveness. You need to know this information to fulfill your OPSEC responsibilities.

**013. Briefly define the historical aspect of operations security and state the purpose of the OPSEC program.**

**OPSEC History.** The success or failure of most major combat operations depends upon the element of surprise. Before an operation can be started, people must be assembled, equipment and transportation massed, and numerous other activities completed. However, when preparing for an operation, we usually show definite patterns of behavior or action. These patterns can become warning signs to enemy intelligence collectors. They can show that an operation is underway or being planned. Attempts to gain information about planned operations is not new; it is an age-old practice. The activities of opposing forces are constantly monitored to obtain signs of planned operations. This is done because such forewarning may provide time to take countermeasures that reduce or eliminate any advantage that may have been created by surprise. In view of this, it is easy to see the need for assuring that sensitive information about our combat operations is controlled.

On the other hand, the need for controlling sensitive information is not as obvious if the information does not seem to be related to a combat operation. Consequently, several Air Force studies were made to find out how sensitive information was being compiled by enemy intelligence sections. For the most part, these studies revealed that sensitive information about combat operations could be obtained, without anyone violating any security rules, by using nothing other than common sense. For example, in Viet Nam, Security Police flight duty schedules and rosters were being posted in locations where foreign nationals could screen them. This was being done as much as 24 hours prior to the scheduled worktime. Moreover, these studies showed that just before a major air strike against Viet Cong targets, we increased our security readiness postures and exercised more strict base entry procedures for foreign nationals.

How many security rules did this violate? NONE. Could these actions provide a trained enemy espionage agent with enough sensitive information to piece together a picture? By themselves, maybe not. But when combined with overheard comments like "We must be getting ready to hit Hanoi; they loaded 500 pounders (bombs) on every plane this afternoon," the picture begins to come into focus.

Under these conditions, the need for an Air Force-wide program to control and protect sensitive information became more and more visible. As a result, the OPSEC program came into being.

**Purpose.** OPSEC is concerned with keeping the tactical and strategic surprise on our side, by protecting information and activities affecting this principle. We must protect knowledge of our plans, resources, and limitations. The proper protection of classified information and material is part of OPSEC; so is the protection of seemingly trivial or insignificant unclassified information and actions which are related. In other words, we must protect information or actions that are sensitive. A simplified statement about the purpose of OPSEC is "to keep the advantage on our side." The successful completion of our mission and the use of OPSEC is greatly dependent upon each individual's recognizing what information and actions need protection. However, there is a point of diminishing returns in applying OPSEC. This point is reached when our overall security measures detract form operational effectiveness. There must be a balance between security mission accomplishment.

**Exercises (013):**

1. How has history shown the need for an OPSEC program?

2. What is the purpose of OPSEC?

**014. List the objectives of the OPSEC program and state the sources and types of information that could forewarn an enemy.**

**OPSEC Objectives.** The OPSEC program is conducted on a full-time basis, as are Air Force programs for information and COMSEC. OPSEC is also similar to these programs in key elements, such as individual responsibility and need-to-know. Specifically, our OPSEC program has four major objectives:

(1) Identify those portions of an operation that require protection.

(2) Develop OPSEC procedures and techniques.

(3) Systematically assess OPSEC status at all operational levels.

(4) Document deficiencies and institute corrective actions.

**Sources and Types of Information.** There are many sources or possible sources of information that give the enemy advance warning. Generally, these can be placed in one of three categories that are common to any military activity: *operations*, *procedural*, and *communications*. Figure 1-6 presents typical intelligence indicators under each of these categories. Within each of the categories there are numerous items of sensitive information. Examples of the types of information that need protection are:

- Objectives of the operation.
- Operation times and locations.
- Friendly and enemy forces involved.
- Known or suspected limitations.
- Methods of employment.

- Results of the operation.
- Sources of intelligence data.
- Methods of data collecting.

**Exercises (014):**

1. What are the objectives of the OPSEC program?

2. What are the sources of information sought by the enemy?

3. What types of information does the enemy use to gain advance warning?

**015. Given hypothetical situations, determine, through lessons learned, if OPSEC objectives and purposes have been met.**

**Lessons Learned.** The main objective of OPSEC is to provide protection for our operations during the planning, execution, and after action phases. Any actions that could affect the successful completion of an operation, or the protection of the mission, fall under OPSEC. One of the most important lessons we have learned about ourselves is the ease with which an enemy can obtain advance knowledge of our operations. We also learned that closely related to this was the apparent lack of importance attached to comments such as we used earlier in this section. Air Force studies of this area also showed that changes to our normal routines contributed to security weaknesses. Finally, and perhaps most startling, was the fact that the Air Force concern for its people was a major factor in creating security weaknesses. This was the result of getting the word out to everyone concerned, thus creating such a grapevine that in some instances the women and children on a base had almost as much knowledge about the what, when, where, why, and how of an operation as the man in charge had.

On that account, we now know that you, the individual at the working level, should be aware of the intelligence impact your information and activity has in relation to the overall security of an operation. Therefore, to do our job under OPSEC, we must

- Change only those procedures or actions that need to be changed.
- Learn to work with those procedures that are needed and cannot be changed.

## OPERATIONS

* Stereotyped sequences of events comprising various phases of the operations.

* Coordination with other agencies that do not have proper safeguards for classification/sensitive information.

* Stereotyped patterns of flight activity (ingress and egress) at a particular location and time.

* Submission of unclassified reports at specific intervals to specific units or levels of command.

## PROCEDURAL

* Public Information releases.

* The posting or transmission of operations orders, flight plans, air traffic control clearances, etc., in unsecure areas.

* The po ing in unsecure areas of duty rosters, transportation schedules, dining hall schedules, etc., which change as a result of an operation order.

* Distinctive emblems or painting on vehicles, buildings, or aircraft.

* Markings on supplies which could reveal the location or starting date of the operations; that is, nicknames, delivery deadlines, etc.

* Logistic buildup or positioning of support materials and facilities.

* Specific briefings, meetings, or religious services.

* The use of nicknames is a particular hazard since a nickname provides an easily recognizable "flag" for numerous actions associated with a particular operation.

* Exercising the plan or testing portions of the plan.

## COMMUNICATIONS

* Plain language communications associated with a planned operation and conducted during the planning, preparatory, and execution phases.

* Use of unchanging or infrequently changing call signs or radio frequencies.

* Stereotyped message characteristics (voice or teletype) which are indicative of particular types of military activity.

* Significant increase or decrease in message traffic volume.

* Activities of new communications facilities in support of an OPLAN.

BBC-112

Figure 1–6. Intelligence indicators.

The need for OPSEC is quite easy to see in combat operations. However, what of peacetime operation and projects? To answer a question with a question, "Why make the opportunity available?" For instance, recall, if you will, the types of operational information that should be protected. Generally subjects, such as objective, time and location, forces, limitations, methods of employment, and data collection, results, and intelligence sources should come to mind. The key point to communicating these subjects is *don't*, unless the person you are talking to has a need-to-know and a secure method of communication is used. This applies equally to combat operations and our peacetime operations.

**Exercises (015):**

1. In each of the following hypothetical situations you are stationed at a Northern U.S. strategic missile base. You are assigned the job of determining if the base OPSEC purposes and objectives are being met. Your survey results in the following information; now you must decide by writing Yes or No in the space provided, whether the OPSEC purposes and objectives were met in each situation.

____ a. The wife of the wing commander appears on the local TV talk show and discusses the importance and benefits of Air Force and local community relations.
____ b. Sitting at the base cafeteria, you overhear two enlisted missile crewmembers talk about a problem they had repairing a malfunctioning launch hoist at Juliet site.
____ c. On sick call, you overhear several dependent wives discussing the distances from their homes to Fox, George, and Romeo sites.
____ d. Your base newspaper has a large front page story of how missile launch crews from your base won the first place award at the last missile competition at Vandenburg AFB, California.
____ e. At the base library you find a copy of a recent IG inspection report and some portions of it are marked "(S)."
____ f. You learn that base reproduction is printing TDY orders for 50 missile crew personnel to attend a school at a classified location in order to learn about a revised missile launch system.

## 1-5. Publications

Your job in the Air Force is quite complex. You are not expected to keep in your mind all of the detailed information needed to do your job. The Air Force has a system of publications that will help you find the information you need to do your job. As a supervisor, you must keep abreast with new developments in all facets of your duties.

Air Force publications are used to announce policies, prescribe procedures, and furnish the instructions you need on your job. If you need technical, administrative, or general information, there is an Air Force publication of some type that covers the situation. This section will cover the types and use of the various publications.

**016. Identify the three types of Air Force publications with a list of selected publications included in each type.**

If you have a thorough knowledge of the various types of Air Force publications, the types of information they contain, how to locate those you need, and how to use them, you have a ready source of information and authority on almost any subject that comes up.

**Types of Air Force Publications.** Whether you need technical or general guidance, you can find it easier if you first try to determine the type of information it is that you need and then look for the answer in that particular type of publication. The types of publications are *standard, specialized,* and *recurring*. Each type is made up of publications that contain elements of information that are similar in content.

*Standard publications*. Standard publications include regulations, manuals, and pamphlets. This type of publication also includes visual aids, bulletins, staff digests, and supplements to some of the standard publications.

*Specialized publications*. These publications contain specialized information not published in any of the standard publications. Included in this type are such publications as stocklists, technical orders, career development courses like the one you are reading at this time, and various training materials.

*Recurring publications*. These publications are nondirective and informal. They include such items as newsletters, briefs, magazines, journals, and narrative summaries.

**Exercises (016):**

1. Match the publications in column A to the types of publications in column B by placing the correct letter in the provided blank.

| *Column A* | *Column B* |
|---|---|
| ____ (1) Regulations. | |
| ____ (2) Stocklists. | a. Standard publications. |
| ____ (3) Newsletters. | b. Specialized publication. |
| ____ (4) Manuals. | |
| ____ (5) Technical Orders. | c. Recurring publication. |
| ____ (6) Briefs. | |
| ____ (7) Pamphlets. | |
| ____ (8) Training materials. | |
| ____ (9) Magazines. | |
| ____ (10) Visual aids. | |
| ____ (11) Journals. | |
| ____ (12) Narrative summaries. | |

**017. Given a list of standard publications and a list of statements describing the type of information contained in the publications, associate the information to the correct publication.**

The standard publications are used to announce policies, assign responsibilities, prescribe procedures, issue

instructions, and give general information. These publications are either directive or nondirective. A directive publication gives detailed information about a specific subject. A nondirective publication contains general information about a subject. Since you will use these publications, you should know the purpose and contents of each of them.

**Types of Standard Publications.** Regulations, manuals, supplements, and operating instructions are directive in nature and prescribe procedural details about how to perform certain tasks. Pamphlets, visual aids, bulletins, and staff digests are nondirective and they are intended for informational or instructional material. Bulletins may, however, include temporary directive-type material not needed for future reference. Now, let's discuss each of the standard publications.

*Regulations.* Air Force regulations (AFRs) are the primary administrative directives that are used for governing Air Force activities. They set up the standard of management and they control the official business of the Air Force. Regulations also announce policies, assign responsibilities, direct actions, and, when necessary, prescribe brief procedural details. The policies outlined in regulations are usually permanent in nature. This means that the purpose or intent of the regulation will remain in effect until a major change in mission or objective has been established.

*Manuals.* Air Force manuals (AFMs) contain permanent and detailed instructions, procedures, and techniques telling people how to do their jobs. A manual may be general and deal with principles or doctrine. It may be a combination of material related to an entire function. It may also be a step-by-step directive telling how to accomplish a specific task or operation. The information in AFMs may be likened to the "How To Do It" articles found in various magazines, or to books on how to fix appliances and automobiles.

*Pamphlets.* Air Force pamphlets (AFPs) usually contain informative rather than directive material. However, some pamphlets are directive in nature such as AFP 85–1, *Electrical Facilities Safe* Practices Handbook. Pamphlets cover a wide range of rather specific subjects. For example, if you are being assigned overseas, you may receive a booklet or brochure concerning the customs, religions, and history of the country in which you will be stationed. Other examples include pamphlets on personal affairs, voting, and first aid.

*Operating instructions.* Operating instructions are similar to regulations but apply only within the issuing headquarters or staff element. Those issued within a headquarters are known as Headquarters Operating Instructions. Those used within a staff office, detachment, missile site, or similar activity are known as Division Operating Instructions or Branch Operating Instructions. Operating instructions may also announce policies and prescribe procedures within a single manager's area of authority. For example, the Operations and Maintenance Chief may issue Maintenance Operating Instructions to personnel under that person's supervision. The content and format of such instructions are at the descretion of the commander or supervisor of the unit.

*Bulletins.* Bulletins contain announcements, notices, and temporary instructions. Temporary directive material of no permanent reference value may also be included. Base bulletins and the weekly publications bulletin are examples.

*Staff digests.* Staff digests contain summaries of significant staff actions, important announcements, and special notices. They are used primarily to keep the commander and his senior staff advised of current matters that would not come to their attention through the normal processes of communication, such as staff meetings. They may be issued daily, weekly, or as required.

*Visual aids.* Visual aids are charts, posters, or graphic illustrations issued for display on walls and bulletin boards. There are two kinds: permanent visual aids and temporary visual aids. Permanent visual aids are issued for explanatory or instructional purposes. An example of a permanent visual aid is a chart portraying military insignia. These aids are numbered and indexed the same as other publications. Temporary visual aids are issued for promotional or motivational purposes. A poster promoting the annual campaign to sell US savings bonds is an example. As a rule, their display period is limited to 30 days, but never more than 90 days. These aids are not numbered, indexed, or retained in permanent record sets.

*Supplements.* A MAJCOM may adapt an Air Force publication to its own needs by issuing a supplement. The supplement must not change the intent or purpose of the original publication; but it can serve to amplify, clarify, interpret, or implement the higher level publication. Similarly, a base may issue a supplement either to a basic Air Force publication or to the basic publication of a MAJCOM (or of any intermediate organization below USAF Headquarters). Each supplement issued becomes an integral part of, and is filed with, the basic publication.

**Exercises (017):**

1. Match the statements in column A to the publications in column B by placing the correct letters in the blank. Some of the statements in column 1 may apply to several publications.

| | *Column A* | *Column B* |
|---|---|---|
| ____ | (1) Directive in nature. | a. Regulations. |
| ____ | (2) Nondirective in nature. | b. Manuals. |
| ____ | (3) Contain permanent and detailed instructions on how to perform a job. | c. Pamphlets. |
| ____ | (4) Contain material on personal affairs, voting, and first aid. | d. Operating Instructions. |
| ____ | (5) Do not change the purpose or intent of the original publication. | e. Bulletins. |
| ____ | (6) Announcements, notices, and temporary instructions. | f. Staff digests. |
| ____ | (7) Apply only within the issuing headquarters or staff element. | g. Visual aids. |
| ____ | (8) Not normally retained in permanent record sets. | h. Supplements. |
| ____ | (9) Contains summaries of significant staff actions. | |
| ____ | (10) Set up the standards of management. | |

*Column A*

_____ (11) May be issued daily, weekly, or as required.
_____ (12) Issued for display on walls and bulletin boards.
_____ (13) Contains information rather than directive material.
_____ (14) Used to clarify a higher level publication.
_____ (15) Announce policies and assign responsibilities.
_____ (16) Can announce policies and prescribes procedures.
_____ (17) May contain a step-by-step directive on how to accomplish a task.
_____ (18) Issued for promotional or motivational purposes.
_____ (19) Become a part of the basic publication.
_____ (20) Control the official business of the Air Force.

**018. Identify the correct technical orders (TOs) from a list of statements describing the information contained in the TO.**

Now that you know how to use standard publications, let's discuss some important specialized publications—TOs. Technical orders provide specific technical information, instructions, and safety procedures pertaining to the installation, operation, maintenance, and modification of Air Force equipment and materials. Think of all the different makes and models of equipment that the Air Force buys and uses. This should make you realize that a great many different technical publications to cover this equipment must be prepared and distributed. To help keep track of all this equipment, the Air Force has classified it into a number of major groups and, then, has classified the publications in the TO system which cover it into the similar groups. Now, let's discuss the various types of TOs.

**Types of Technical Orders.** At the present time, the TO system contains six major types: (1) technical manuals, (2) time compliance, (3) methods and procedures, (4) index type, (5) abbreviated, and (6) automation TOs. Refer to figure 1-7 and locate these TOs on the top part of the figure. Study the breakdown under each type as we described it in the following paragraphs.

*Technical manuals (TM).* Technical manuals are perhaps the most important type of TOs used by the specialist and technician. They contain detailed information required for the operation, maintenance, inspection, installation, and overhaul of equipment. These manuals are grouped into a number of main categories that cover equipment such as aircraft, missiles and space systems, ground communications and electronic equipment, standard and special tools, and nonaeronautical engines and components, just to name a few. A good example of a TM type TO that applies to your job is 34Y19–1–1, *Use, Care, and Maintenance of Electric Motors*. Another example is the TO 32–1–2, *Use of Hand Tools*.

*Time compliance technical orders (TCTOs).* The time compliance TO is an authorized method of providing instructions for various types of maintenance action. The instructions may include such actions as equipment modification, the performance of some special inspections, or a change in operating procedures. The instructions are issued to correct unsafe conditions that could result in a fatal accident or severe injury to personnel or the destruction of property. The time involved for the work to be done depends upon the degree of danger caused by the unsafe condition.

Time compliance TOs, as the name implies, must be complied with in a certain specified time. The TOs are grouped according to the importance and urgency of the instructions. The degree of urgency is indicated by specifying when the work will be done. For example, if an unsafe condition could result in fatal or serious injury to personnel or extensive damage to valuable property, the corrective instructions would reflect immediate action and the equipment is removed from use until the condition is corrected. An urgent action TO is issued if the risk involved is tolerable only within definite time limits. If the condition is not corrected within 10 days, the equipment is removed from service. If the defects or conditions are not extremely serious at the present time, but must be corrected to forestall equipment failure, the instructions would reflect routine action.

Routine action TOs specify that the work must be done within a certain number of days or at the next inspection period. When the change must be made by a contractor or a specific AF activity, a record-type TO is issued. When the urgency of conditions does not allow time for printing and distribution of instructions in formal TO format, the instructions are distributed by means of interim-type TOs. This interim TO information is sent by radiogram, telegram, teletype, or other means of high speed communication. This TO is usually replaced with an immediate or urgent action TO within 10 days.

*Methods and procedures TOs (MPTOs).* The MPTOs provide information and instructions on safe methods and procedures relating to such subjects as preventive maintenance, periodic inspections, and specific policies and procedures. In this way, they differ from technical manuals which deal with specific items of equipment. The MPTOs are divided into two classes. One class involves policies, methods, and procedures relating to maintenance or administration. The other class involves policies, methods, and procedures relating to equipment in general.

*Index type TOs.* A good publications system must be properly indexed for the use and convenience of using personnel. Technical order indexes show the status of all TOs, provide personnel with a means of selecting needed publications, and, in certain instances, group the TOs pertaining to specific items of equipment. Examples of index type TOs are the numerical and alphabetical indexes. We are only mentioning indexes here as a type of TO. We shall discuss these publications in more detail later in the chapter.

*Abbreviated TOs.* These are TOs published on smaller paper or cards with data included that is extracted from some other document, usually another TO. This type of TO is primarily a work simplification device. Included in these TOs are work simplification aids such as checklists,

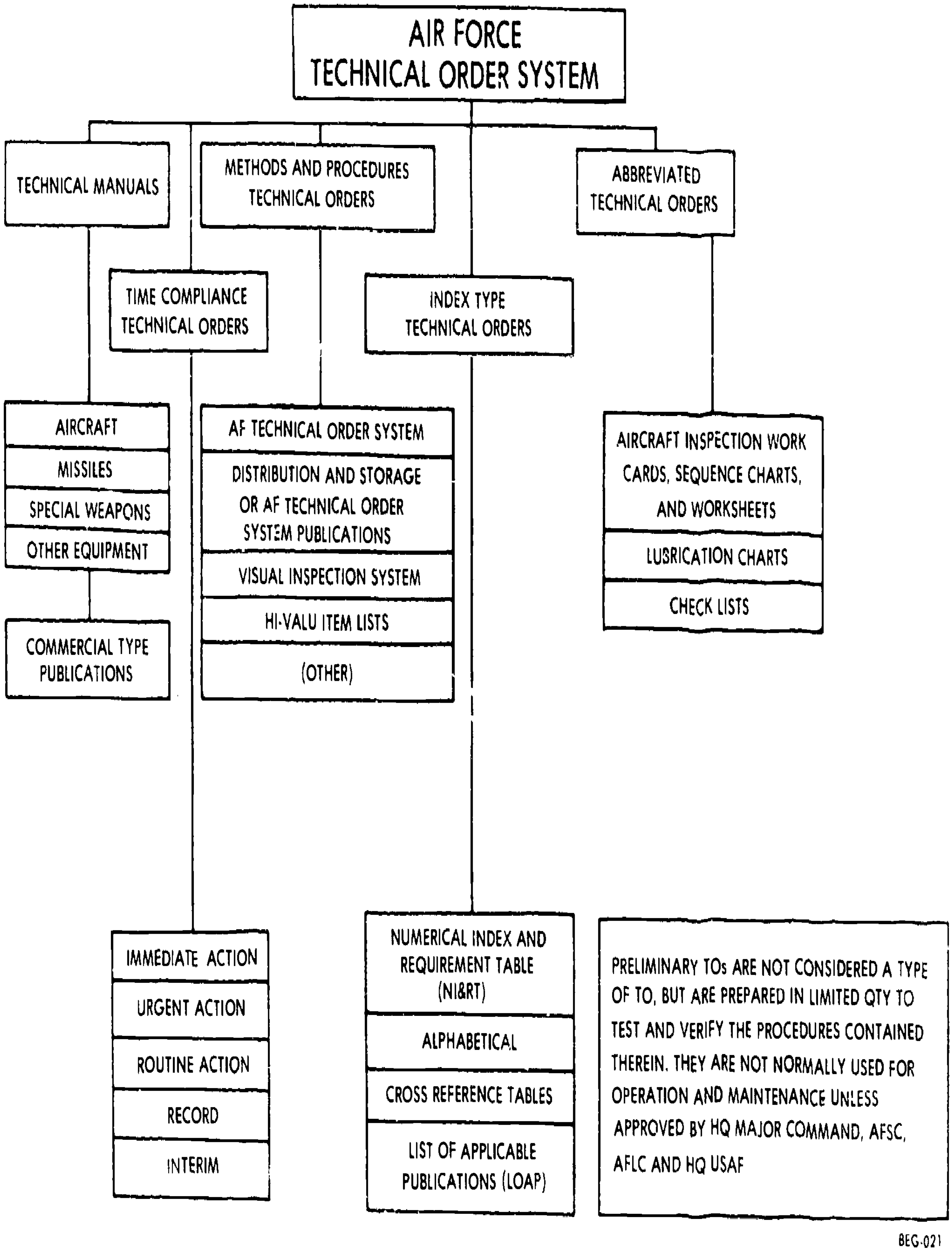


Figure 1-7. Types of technical orders

inspection workcards, lubrication charts, and inspection sequence charts.

**Exercises (018):**

1. Match the statements in column A to the related publications in column B by placing the correct letter of the related publication in the provided blank.

| *Column A* | *Column B* |
|---|---|
| _____ (1) This publication is for the specialist or the technician. | a. Technical manuals. |
| _____ (2) These TOs are issued to resolve unsafe conditions that could result in a fatal accident. | b. Time compliance TOs. |
| _____ (3) These publications show the status of all TOs. | c. Methods and Procedures TOs. |
| _____ (4) These TOs involve policies and procedures related to equipment in general. | d. Index Type TOs. |
| _____ (5) This TO is published on small paper or cards. | e. Abbreviated TOs. |
| _____ (6) This TO contains detailed information required for operation and maintenance of equipment. | |
| _____ (7) The TOs that provide general information on methods related to maintenance management. | |
| _____ (8) This TO is a work simplification device. | |
| _____ (9) The instructions in this TO must be done within a specified time. | |
| _____ (10) The information in these TOs is listed in numerical and alphabetical order. | |
| _____ (11) This TO is issued to correct an unsafe condition. | |
| _____ (12) The detailed information in this TO is used to guide the operation and maintenance of power tools. | |
| _____ (13) This TO is sent by telegram or teletype. | |
| _____ (14) These TOs are in the form of workcards and charts. | |
| _____ (15) The information in this TO is of a general nature. | |
| _____ (16) The TOs that provide personnel with a means of selecting needed publications. | |

**019. State how commercial publications are acquired, identified, and indexed.**

**Commercial Publications.** Occasionally, you will need technical instructions concerning an item of equipment or a work procedure for which a TO has not been published. In such cases, you must know how to find and use commercial technical publications. Commercial technical publications may come in any form, such as a manual, book, leaflet, or pamphlet. They may contain technical information on assembly, installation, operation, servicing, overhaul, and parts identification.

Some commercial publications are included in the TO system. When the Air Force Logistics Command (AFLC) deems it necessary, a commercial publication is given a TO number and is put into the TO system. Technical order numbers are placed on them and they should be dated. In some cases a one-sheet "identifying" TO is issued as a title sheet to describe the item and, when necessary, to supply additional instructions. These publications may be filed in the TO binders in numerical order with the regular TOs or they may be filed in a separate file in numerical order. When in the regular TO file, the identifying title sheet is filed just in front of the commerical publication. If kept in a separate file, the identifying title sheet is filed in the regular TO file in numerical order and a notation is put on it to show where the publication is filed.

Commercial publications that have been put into the Air Force TO system are listed in the appropriate numerical index and requirement tables.

There will be times when you need commercial publications that are not included in the TO system. In some cases, Air Force organizations buy items of equipment off the shelf in the local area or buy items in very small quantities. The publications required in these cases are limited to just a few copies and consist of operation manuals, service and maintenance manuals, and parts lists. When this happens, the only source of information is the commercial publications available from the manufacturer of the equipment. Since these publications are not used throughout the Air Force, they are not placed in the TO system. These publications are bought through local procurement from the equipment manufacturer. There are other commercial publications you may need such as specialized instructions, standards, and codes that are not put in the publication system for various reasons. The main reason is one of economics. It is cheaper to buy what is already printed when the instructions meet Air Force needs. In any case, if publications of this type are needed, they must be purchased through local procurement. Commercial publications purchased by the Air Force in this manner are neither put in the TO file nor shown in the TO indexes. Unnumbered commercial publications should be kept together in some logical order in a section or shelf of a publications filing cabinet readily available to everyone.

**Exercises (019):**

1. How are commercial publications identified when they are a part of the TO system?

2. How are commercial publications filed when they are part of the TO system?

3. How are commercial publications indexed when they are a part of the to system?

4. State two reasons why some commercial publications (commercial manuals) needed by the Air Force are not included in the TO system?

5. List some other commercial publications besides operations and maintenance manuals that are not in the Air Force system.

6. How are publications not in the system purchased?

7. How are commercial publications not in the TO system indexed and filed?

**020. Select the identifying and indexing methods and techniques for standard publications and TOs.**

As you already know, there are a great number of subjects important to you. These subjects are contained in AF standard publications and Tech Orders. Much time and effort would be lost if you had to search through all the existing publications to find the particular subject you need. Therefore, if we are to quickly locate the desired subject, we must have a method of identifying the publication containing the information we need.

**Identification of Standard Publications.** A method for easy and quick identification of Air Force publications is important because of the large variety of publications required by the many units and organizations within the Air Force. A system of letters, numbers, and titles has been developed to indicate the subject matter of the publications and to assist in the indexing of them.

*Alphabetical and numerical identification.* The Air Force has adopted a dual identification system. This system consists of an alphabetical prefix and a number code of two or more groups of digits. The alphabetical prefix identifies the type of publication and the level at which it was originated. The prefix may look like this. "AFR, AFM, or AFP." The "AF" indicates that the publication originated at Headquarters USAF. The "R" indicates that the publication is a regulation; the "M" stands for manual; and the "P" means that it is a pamphlet. The numerical code consists of a basic subject series number and a specific item number. The series number identifies the subject that most closely relates to the title and content of the publication. See figure 1-8 for examples of series numbers and subjects. The actual list is in alphabetical order as you will see later. The item number is preceded by a dash to separate it from the series number and identifies the specific publication. Operating instructions and visual aids are also identified by the same system. However, the staff digests and bulletins are numbered in sequence, starting with number 1 at the beginning of each calendar year. Now let's look at the complete number of a publication. Let's use as an example, AFR 85-1. The AFP indicates that the publication is an Air Force pamphlet; the 85 is the series number indicating the subject of Civil Engineering General; the -1 indicates the specific publication of Electrical Facilities Safe Practice Handbook. Now, that you know how to identify a standard publication, let's find out how the publications are indexed and filed.

*Indexing system.* It would be impossible to remember the number and title of each Air Force publication. The indexes, then, are important to you because locating the desired publication can be speeded up by their use. The key is to learn to use the indexes. They are prepared and issued as Air Force Regulations—the "O" series. See figure 1-9 for a section of AFR 0-2 which lists all the indexes. As you can see, there is quite a number of indexes listed and they cover a wide variety of publications and forms which are used to meet various Air Force needs. The index in this list that you will use most often is the AFR 0-2 *Numerical Index of Standard and Recurring Air Force Publications.* The publications contained in this index are listed by series number and by specific number. Recurring periodicals and visual aids are also listed in this index in numerical order right after the alphabetical list of series numbers at the front of the regulation. Next, the Air Force regulations, manuals, and pamphlets are listed in numerical order according to subject series numbers. Look at figure 1-10 and notice the 4 series numbers—81, 82, 84, and 85. The specific publications in each of these series are listed in numerical order. Look again at figure 1-10 and note the headings for each of these series. The subjects related to the series numbers are listed in alphabetical order inside the front cover of the regulation. Figure 1-11 shows this alphabetical listing. The list is used to identify the subject series numbers. The list contains only the general subject areas; none of the actual publication titles are listed. However, the use of the alphabetical list, followed by use of the numerical list will let you identify the desired publication by title and number.

A little more needs to be said about the other indexes shown in figure 1-9. You will need to use some of them from time to time. The titles on these indexes show the type of publications that are listed in them. One that you have a need for is AFR 0-8, *Index of Specialty Training Standards,* which you use to see that you have the current training standard for your trainees. Another index you should find very useful is AFR 0-9, *Numerical Index of*

| Series Number | Subject |
|---|---|
| 0- | Indexes |
| 1- | Aerospace Doctrine |
| 5- | Publications Management |
| 9- | Forms Management |
| 10- | Administrative Communications |
| 11- | Administrative Practices |
| 30- | Personnel |
| 35- | Military Personnel |
| 36- | Officer Personnel |
| 39- | Enlisted Personnel |
| 40- | Civilian Personnel |
| 50- | Training |
| 67- | Supply |
| 77- | Motor Vehicles |
| 85- | Civil Engineering - General |
| 86- | Civil Engineering Programming |
| 87- | Real Property Management |
| 88- | Facility Design and Planning |
| 90- | Housing |
| 91- | Real Property Operation and Maintenance |
| 92- | Civil Engineering Fire Protection |
| 93- | Special Civil Engineering |
| 111- | Military Justice |
| 127- | Safety |
| 205- | Security |

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Figure 1-8. Series number designation.

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SECTION C—REGULATIONS, MANUALS, AND PAMPHLETS (Short Titles: AFR, AFM, AFP)

| *Number* | *Date* | *Title* | *OPR* | *Distr* |
|---|---|---|---|---|
| **0—INDEXES** | | | | |
| R 0-1 | 1 Sep 74 | Guide to Indexes, Catalogs, and Lists of Departmental Publications | DAPS | F |
| R 0-2 | 1 Apr 80 | Numerical and Index of Standard and Recurring Air Force Publications | DAPDQ | F |
| R 0-4 | • 15 Oct 80 | Department of Defense, Joint Chiefs of Staff, & Interservice Publications and Air Force Acquisition Documents | DAPP | F |
| R 0-5 | • 8 Sep 80 | Specialized COMSEC Publications | XOKCR | F |
| R 0-7 | 9 Apr 80 | Index of Air Force Personnel Tests | MPC/MPCY | F* |
| Changes | | 1 | | |
| R 0-8 | • 1 Feb 81 | Numerical Index of Specialty Training Standards | MPC/MPPT | F* |
| R 0-9 | •21 Nov 80 | Numerical Index of Departmental Forms | DAPSF | F |
| R 0-10 | 1 Apr 80 | Management Control and Authorization Program of Allowance Source Codes for USAF Activities | LEYSP | F |
| R 0-12 | • 9 Dec 80 | Functional Index of Departmental Forms | DAPSF | F |
| R 0-13 | 26 Jul 78 | Civilian Personnel Publications | DAPDQ | F |
| R 0-14 | 1 Aug 79 | Civil Engineer Publications | DAPDQ | F |
| R 0-15 | • 5 Sep 80 | Defense Intelligence Agency (DIA) and Specialized USAF Intelligence Publications | DAPDQ | F |
| R 0-16 | 24 Jul 78 | Miscellaneous Federal Government and Commercial Publications | DAPDQ | F |
| R 0-17 | •28 Nov 80 | Air Force Occupational Safety and Health (AFOSH) Standards; Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) Publications | IGDSI | F |
| R 0-18 | • 1 Nov 80 | Index of Air Force Manpower Standards | MEA/MEMD | F* |

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Figure 1-9. Index listing.

## SECTION C—REGULATIONS, MANUALS, AND PAMPHLETS (Short Titles: AFR, AFM, AFP)

| Number | Date | Title | OPR | Distr |
|---|---|---|---|---|
| **81—SPECIFICATIONS AND STANDARDS** | | | | |
| R 81-10 | 2 Jun 75 | Engineering Drawing System | LEYE | F |
| R 81-11 | 2 Jun 75 | Engineering Drawing Change System | LEYE | F |
| **82—DESIGNATING AND NAMING DEFENSE EQUIPMENT** | | | | |
| R 82-1 | 9 Apr 76 | Military Aircraft, Rockets, and Guided Missiles | PAXR | F |
| R 82-2 | 11 Feb 74 | Joint Electronics Type Designation System | LEYEK | F |
| R 82-3 | 7 Oct 74 | Military Aircraft, Rockets, and Guided Missiles | PAXR | F |
| R 82-4 | 15 Jan 80 | Designating Aeronautical and Support Equipment | LEYM | F |
| R 82-7 | 4 Apr 79 | Designating and Redesignating Air Force Electronics Equipment | LEYEK | F |
| IMC | | 79-1 | | |
| **84—PRODUCTION** | | | | |
| R 84-4 | 3 Apr 75 | Munitions and Equipment Production Schedule, (RCS: HAF-LGY(M)7135) | LEYW | X |
| R 84-8 | 26 Aug 74 | Reports on Production of Aircraft, Missiles, and Engines, (RCS: HAF – RDG(M)7102) | RDGB | F |
| **85—CIVIL ENGINEERING GENERAL** | | | | |
| + R 85-1 | 22 Sep 78 | Resources and Work Force Management | ESC/DEMG | F* |
| IMC | | 79-1 80-1 80-2 •80-3 | | |
| – P 85-1 | 14 Nov 67 | E... ..cilities Safe Practices Handbook (Reprint, 28 May 74, i... s changes 1 and 2) | ESC/DEMM | F* |
| Changes | | | | |
| IMC | | 79-1 •80-1 | | |
| EMC | | 77-1 | | |
| R 85-2 | 26 Nov 68 | Family Housing for Essential Employees at Research and Development Installations (PA) | LEEH | F |
| + M 85-3 | 15 Jan 69 | Paints and Protective Coatings (Reprint includes Change 1) | ESC/DEMM | F* |
| R 85-4 | 30 Oct 63 | Implementing Guarantees of Equipment Installed in AF Construction | ESC/DEMM | F* |
| + M 85-5 | 1 Nov 65 | Maintenance and Operation of Cathodic Protection Systems (Reprint Includes Change 1) | ESC/DEMM | F* |
| M 85-6 | 30 Aug 63 | Land Management and Grounds Maintenance (Reprint, 26 Aug 77, includes change A) | ESC/DEVN | F* |
| + R 85-7 | 20 Apr 76 | MAJCOM Engineering and Services Organizations and Functions | ESC/DEMG | F* |
| IMC | | 80-1 | | |
| R 85-8 | 31 Mar 77 | Maintenance and Repair of Surface Areas | ESC/DEMP | F* |
| – R 85-9 | 1 Mar 76 | Inactive Installations-Inactivation and Maintenance | ESC/DEMM | F* |
| IMC | | 77-1 79-1 | | |
| + R 85-10 | 24 Oct 75 | Operation and Maintenance of Real Property | ESC/DEMG | F* |
| Changes | | 1 2 3 | | |
| IMC | | 80-1 | | |
| P 85-11 | 15 Sep 80 | Financial Management Guide | ESC/DEM | F* |
| M 85-12 | | Operation and Maintenance of Central Heating Plants and Distribution Systems | ESC/DEMM | F* |
| Vol 1 | 1 Jun 64 | | | |
| Changes | | A B C D | | |
| Vol 2 | 15 Jun 64 | Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization | ESC/DEMM | F* |
| – M 85-13 | 5 Feb 59 | Maintenance and Operation of Water Plants and Systems (Reprint, 15 Jun 68, includes Changes A thru D) | ESC/DEMM | F* |
| + M 85-14 | 5 Jan 59 | Maintenance and Operation of Sewage and Industrial Waste Plants and Systems (Reprint, 1 Sep 67, includes Change A) | ESC/DEMM | F* |
| M 85-15 | 1 Jun 56 | Coal Handling (Reprint, 1 Feb 68, includes Changes A and B) | ESC/DEMM | F* |
| Changes | | C | | |

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Figure 1–10. Typical page from AFR 0–2.

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| Subject | No. |
|---|---|
| Accounting and Finance | 177 |
| Acquisition Management | 800 |
| Administration Management | 4 |
| Administrative Communications | 10 |
| Administrative Practices | 11 |
| Aeromedical Evacuation | 164 |
| Aerospace Doctrine | 1 |
| Aerospace Medicine | 161 |
| Aerospace Operational Doctrine | 2 |
| Aerospace Systems Security | 207 |
| Air Base Defense | 206 |
| Armament | 136 |
| Audio-Visual Systems | 95 |
| Auditing | 175 |
| Automatic Data Processing Systems and Procedures | 171 |
| Awards, Ceremonies, and Honors | 900 |
| Budget | 172 |
| Chaplain | 265 |
| Civil Air Patrol | 46 |
| Civil Engineering General | 85 |
| Civil Engineering Programming | 86 |
| Civil Engineering – Fire Protection | 92 |
| Civilian Personnel | 40 |
| CLAIMS | 112 |
| Command and Control and Communications | 102 |
| Commissaries | 145 |
| Communications – Electronics | 100 |
| Comptroller | 170 |
| Contracting and Acquisition | 70 |
| Contractor Data Management | 310 |
| Cost Analysis | 173 |
| Data Automation | 300 |
| Dental Services | 162 |
| Dependents' Education | 214 |
| Designating and Naming Defense Equipment | 82 |
| Disaster Preparedness | 355 |
| Documentation | 12 |
| Educational Services Program | 213 |
| Electronic Systems | 101 |
| Energy Conservation | 18 |
| Enlisted Personnel | 39 |
| Environmental Protection | 19 |
| Equipment Maintenance | 66 |
| Exchange Service | 147 |
| Facility Construction | 89 |
| Facility Design and Planning | 88 |
| Federal Supply Cataloging | 72 |
| Flying Training | 51 |
| Flying | 60 |
| Food Service | 146 |
| Forms Management | 9 |
| Fuels, Propellants and Chemicals | 144 |
| Graves Registration and Mortuary Affairs | 143 |
| Historical Data and Properties | 210 |
| Housekeeping and Nonhousekeeping Quarters | 140 |
| Housing | 90 |
| Indexes | 0 |
| Industrial Resources | 78 |
| Information | 190 |
| Inspection | 123 |
| Intelligence | 200 |
| Judge Advocate General | 110 |
| Laundry and Dry Cleaning | 148 |
| Libraries | 212 |
| Logistics | 400 |
| Maintenance – Engineering and Supply | 65 |
| Management Analysis | 178 |
| Management Engineering | 25 |
| Manpower | 26 |
| Mapping, Charting, and Geodesy | 96 |
| Materiel Programming | 401 |
| Medical Administration | 168 |
| Medical Education and Research | 169 |
| Medical Materiel | 167 |
| Medical Service | 160 |
| Military Airlift | 76 |
| MILITARY JUSTICE | 111 |
| Military Personnel Procurement | 33 |
| Military Personnel | 35 |
| Military Records | 31 |
| Mission Employment Tactics | 3 |
| Morale, Welfare, and Recreation | 215 |
| Motor Vehicles | 77 |
| Natural Resources | 126 |
| Nonappropriated Funds | 176 |
| Nuclear Safety | 122 |
| Officer Personnel | 36 |
| Operational Requirements | 57 |
| Operations | 55 |
| Organization and Mission – Departmental | 21 |
| Organization and Mission – Field | 23 |
| Organization and Mission – General | 20 |
| Oversea Areas | 216 |
| Packaging and Materials Handling | 71 |
| Personal Affairs | 211 |
| Personnel Services | 34 |
| Personnel | 30 |
| Postal and Courier Operations | 182 |
| Production | 84 |
| Programming | 27 |
| Publications and Forms Requirements and Distribution | 7 |
| Publications Management | 5 |
| Quality and Reliability Assurance | 74 |
| Real Property Management | 87 |
| Real Property Operation and Maintenance | 91 |
| Reproduction | 6 |
| Research and Development | 80 |
| Reserve Forces | 45 |
| Safety | 127 |
| Schools | 53 |
| Search and Rescue | 64 |
| Security Police | 125 |
| Security | 205 |
| Special Civil Engineering | 93 |
| Special Investigations | 124 |
| Special Publications Systems | 8 |
| Specifications and Standards | 81 |
| Standardization | 73 |
| Storage and Warehousing | 69 |
| Supply | 67 |
| Technical Training | 52 |
| Training | 50 |
| Transportation and Traffic Management | 75 |
| Value Engineering | 320 |
| Veterinary Service | 163 |
| War Planning | 28 |
| Weather | 105 |
| Writing Improvement | 13 |

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Figure 1-11. Alphabetical list of subjects in AFR 0-2.

*Departmental Forms*. This index lists forms used by the Air Force which are listed by type and then in numerical order. The types of forms listed are Air Force (AF), Communications Security (AFCOMSEC), Air Force Technical Order (AFTO), Department of Defense (DD), Standard and Stock (SF), Optional (OF), and other Government Agency Forms. Also, it includes accountable forms, forms requiring storage safeguards, forms requisitioned quarterly, forms covered by a blanket privacy act statement, and obsolete forms. AFR 0–10, *Management Control and Authorization Program of Allowance Source Codes for USAF Activities*, lists the table of allowances that apply to your shop. AFR 0–14, *Civil Engineer Publications*, lists civil engineer publications of the Department of Defense, Army, and Navy that are applicable to the Air Force CE functions. One last index that you have a need for is AFR 0–17, *Air Force Occupational Safety and Health (AFOSH) Standards; Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) Publications*. AFOSH standards have replaced several sections of AFR 127–101, *Ground Accident Prevention Handbook*. AFR 0–17 tells you the standards you need in your shop.

**Identification of Technical Orders.** Just as standard publications have a numbering system, so do TOs. You recall that standard publications are assigned a basic series number. Technical orders have a similar number assigned called a category number.

*TO categories*. Air Force equipment has been divided into groups according to type and use. These groups are assigned a publications category number. Each category is given a primary number. Some categories are subdivided because of the large amount of equipment and material they cover. For example, category 32, standard and special tools TOs, is not divided. Category 33, general purpose test and associated equipment, is divided into five subdivisions. At the present time, there are 41 categories in use. Figures 1-12A and 1-12B give a complete list of primary AFTO categories with their titles. There are two other categories not shown in figure 1-12 that are for a special purpose and are not available through the regular TO system and do not pertain to your work.

*TO indexes*. Technical orders which list other technical orders are called index TOs. There are several kinds of index TOs in use. The most frequently used indexes are the numerical index and requirement tables (NI&RT). They list TOs by identifying numbers and titles. There is also an alphabetical index which lists types of equipment alphabetically and the TO number group for equipment listed. There are also two indexes which are used as cross-reference tables.

Index TOs give personnel a way to select needed TOs, show the status of all TOs, and, in certain instances, group the TOs that pertain to specific items of equipment. A description of the types of indexes issued is covered in the following paragraphs. The second number in the index TO number indicates the type of index.

*a*. Numerical Index and Requirement Tables. TO 0–1–01 is known as the index of indexes. It lists all the other NI&RTs. As the name of the index implies, it is a list of index TOs in numerical order. Each TO category will have its own NI&RT. The TO number for all NI&RTs will start with 0–1. As an example, the NI&RT for standard and special tools is 0–1–32, and the one for common hardware equipment is 0)en1–44.

*b*. Alphabetical Listing of Equipment to TO Number Groups. This TO provides an easy way for locating the correct TO number group when the type of equipment is known. The index of alphabetical listings is numbered 0–2–1.

*c*. Cross-Reference Table of TCTO Numbers to Applicable Data Code Numbers. This TO provides a cross-reference listing of data code numbers assigned to active TCTOs. Cross-reference tables start with 0–4.

*d*. List of Applicable Publications (LOAP). This is a TO in index form that lists all the TOs that are needed to operate, maintain, and repair a major equipment system such as the F–15 fighter, a Titan missile, or a ground radar system. The TO number for a specific LOAP is found in the applicable category index that lists the TOs for the equipment. It will be the first TO number listed under the item of equipment and the number always ends with 01; for example, 21M–LGM25C–01. This LOAP lists all the TOs that are needed with the Titan missile including tools, test equipment, etc. This TO would be included in the limited TO file that is kept on the equipment.

Figure 1-13 13 shows examples of how TO numbers are broken down. Notice each number has a specific meaning. The first number, 90–1–32, is an example of a TO number as it would appear in TO 0–1–01. The second 3 part number and the 4 part number are as they would appear in the category index. Each index TO preface will contain a similar breakdown with a full explanation of the meaning of each number.

*TO files*. TOs are placed in binders in the same order as they are listed in the numerical indexes, and the binders are filed by binder number. In other words, the TOs are filed in numerical sequence beginning with 0–1–01. When alphabetical lettering is involved, TOs will also be filed according to their alphabetical sequencing as well as their numerical sequence. One binder may contain one or more TOs. For this reason, the numbers of the first and last TO in a binder are shown on a tab located on the back of each binder. Figure 1-14 shows an example of TOs in a file. As you can see in figure 1-14, the book number is written on the top of each tab to help you return the binder to the proper place in the file.

**Exercises (020):**

1. Place an X by the statements that best describe the identification method and techniques for standard publications. Some blanks may not require an entry.

____ a. Standard publications are identified only by an alphabetical prefix.

____ b. The identification system consists of an alphabetical prefix and a number code of two or more groups of digits.

____ c. Standard publications use only numbers and digits for identification.

| CATEGORY TO | NI&RT | TITLE |
|---|---|---|
| 01 | 0-1-01 | Numerical Index and Requirements Tables, Numerical Index, Alphabetical Indexes, and Cross Reference Table Technical Orders. |
| 00 | 0-1-02 | General Technical Orders |
| 1 | 0-1-1 Series | Aircraft Technical Orders |
| 2 | 0-1-2 Series | Airborne Engine Orders |
| 3 | 0-1-3 Series | Aircraft Propellers and Associated Equipment Technical Orders |
| 4 | 0-1-4 Series | Aircraft Landing Gear Components and Associated Equipment Technical Orders |
| 5 | 0-1-5 Series | Airborne Instrument Technical Orders |
| 6 | 0-1-6 Series | Aircraft and Missile Fuel Systems and Equipment Technical Orders |
| 7 | 0-1-7 Series | Airborne Engine Lubricating Systems and Associated Equipment Technical Orders |
| 8 | 0-1-8 Series | Airborne Electrical Systems Technical Orders |
| 9 | 0-1-9 Series | Airborne Hydraulic, Pneumatics and Vacuum Systems Technical Orders |
| 10 | 0-1-10 Series | Photographic Equipment, Supplies, and Sensitized Materials Technical Orders |
| 11 | 0-1-11 Series | Armament Technical Orders |
| 12 | 0-1-12 Series | Airborne Electronic Equipment Technical Orders |
| 13 | 0-1-13 Series | Aircraft Furnishing, Cargo Loading and Aerial Delivery, and Firefighting Equipment Technical Orders |
| 14 | 0-1-14 Series | Deceleration Devices, Personal and Survival Equipment Technical Orders |
| 15 | 0-1-15 Series | Aircraft and Missile Temperature Control, Pressurizing, Air Conditioning, Heating, Ice Eliminating, and Oxygen Equipment Technical Orders |
| 16 | 0-1-16 Series | Airborne Mechanical Equipment Technical Orders |
| 21 | 0-1-21 Series | Guided Missile Technical Orders |
| 22 | 0-1-22 Series | Aerospace Technical Orders |
| 31 | 0-1-31 Series | Electronic Technical Orders |

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Figure 1-12A. Technical order categories and titles.

| | | |
|---|---|---|
| 32 | 0-1-32 Series | Standard and Special Tools Technical Orders |
| 33 | 0-1-33 Series | General Purpose Test and Associated Equipment Technical Orders |
| 34 | 0-1-34 Series | Shop Machinery and Associated Equipment Technical Orders |
| 35 | 0-1-35 Series | Ground Handling, Support and Base Operating Equipment Technical Orders |
| 36 | 0-1-36 Series | Vehicles, Construction and Materials Handling Equipment and Equipment and Components Technical Orders |
| 37 | 0-1-37 Series | Fuel, Oil, Propellant Handling and Associated Equipment Technical Orders |
| 38 | 0-1-38 Series | Nonaeronautical Engines and Components Technical Orders |
| 39 | 0-1-39 Series | Watercraft and Associated Equipment Technical Orders |
| 40 | 0-1-40 Series | Commercial Air Conditioning, Heating, Plumbing, Refrigerating, Ventilating, and Water Treating Equipment Technical Orders |
| 41 | 0-1-41 Series | Subsistence and Food Service Equipment Technical Orders |
| 42 | 0-1-42 Series | Chemical, Oxygen, Metal, Textile, Fuels, Cordage, Lumber, and Rubber Materials (Dopes, Cleaning Compounds, Glues, Gases, Lubricants, Paints, Plastics, etc) Technical Orders |
| 43 | 0-1-43 Series | Training Devices and Associated Equipment Technical Orders |
| 44 | 0-1-44 Series | Common Hardware Equipment Technical Orders |
| 45 | 0-1-45 Series | Railroad and Associated Equipment Technical Orders |
| 46 | 0-1-46 Series | Office, Duplicating, Printing and Binding Equipment Technical Orders |
| 47 | 0-1-47 Series | Agricultural Equipment Technical Orders |
| 49 | 0-1-49 Series | Optical, Instruments, Timekeeping, and Navigation Equipment Technical Orders |
| 50 | 0-1-50 Series | Special Service Equipment Technical Orders |
| 51 | 0-1-51 Series | General Purpose Automatic Test System and Versatile Automatic Test Sytems Technical Orders |
| 60 | 0-1-60 Series | Explosive Ordnance Disposal Technical Orders |

BEG-467

Figure 1-12B. Technical order categories and titles.

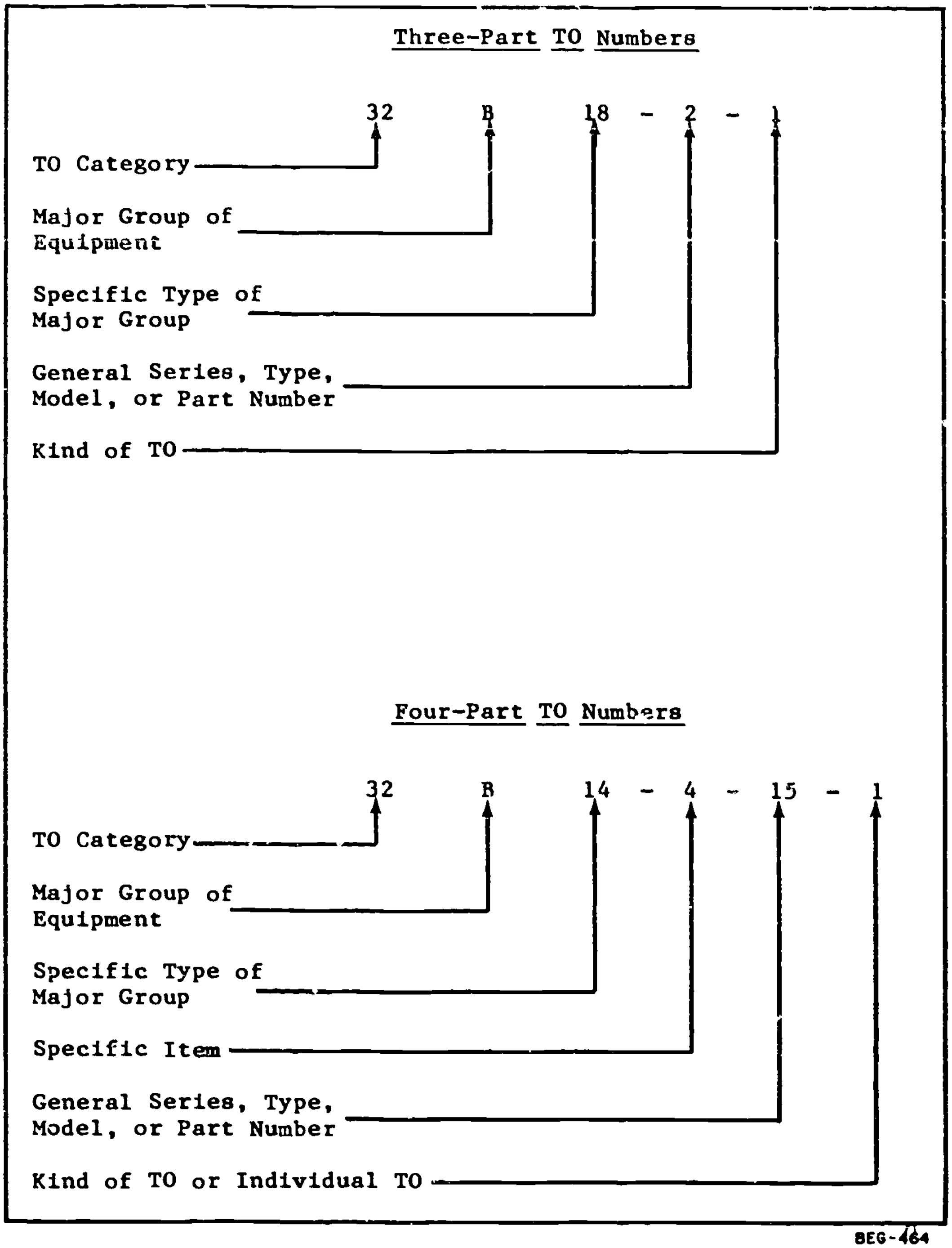


Figure 1–13. TO number breakdown.

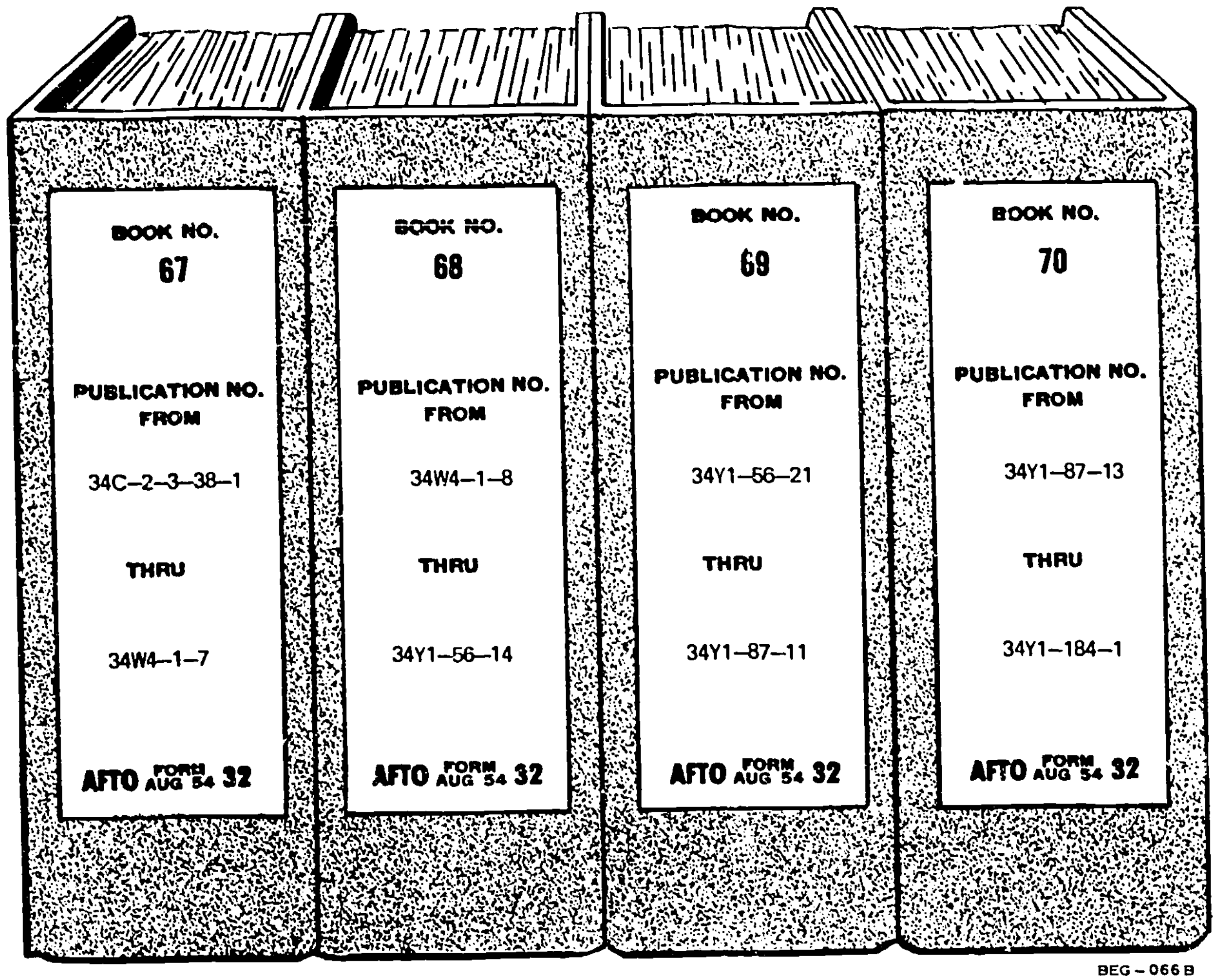


Figure 1-14. Technical order binders.

____ d. The AFM prefix indicates an Army publication.
____ e. The type of publication is identified by an alphabetical prefix.
____ f. The numerical code consists of a basic series number and a specific item number.
____ g. The series number identifies the related subject and content of the publication.
____ h. The specific publications are identified by letters preceded by a dash.
____ i. Staff digests and bulletins are identified by letters and dashes.
____ j. An AFP prefix indicates an Air Force pamphlet.

2. Mark the following statements about indexing methods and techniques for standard publications true or false by entering a T or F in the space provided. Correct the false statements.

____ a. The standard publication indexes are prepared and issued as Air Force manuals.
____ b. The standard publication indexes are prepared and issued as Air Force Regulations.
____ c. The indexes are issued as the "O" series publications.
____ d. The publications in the indexes are listed alphabetically and numerically.
____ e. The publications in the indexes are listed in numerical order by series numbers and by specific number under the series number.
____ f. The titles of the specific publications are listed in alphabetical order.
____ g. The alphabetical listing in the front of AFR 0-2 contains the titles of the publications.
____ h. The alphabetical list in the front of AFR 0-2 contains general subject areas used to identify the series numbers.

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3. Match the statements about indexes in column A with the correct index number in column B by entering the proper letter in the space provided. Some indexes may be used more than once and others may not be used at all.

| Column A | Column B |
|---|---|
| ____ (1) Lists tables of allowances for you shop. | a. AFR 0–1. |
| ____ (2) Includes Army and Navy civil engineering publications. | b. AFR 0–2. |
| ____ (3) Shows current date of Department of Defense forms used by the AF. | c. AFR 0–4. |
| ____ (4) Is a guide to indexes. | d. AFR 0–7. |
| ____ (5) Provides a list of permanent visual aids. | e. AFR 0–8. |
| ____ (6) Used to find current date of S 542X0. | f. AFR 0–9. |
| ____ (7) Has an alphabetical list of general subject areas covered by standard publications. | g. AFR 0–10. |
| ____ (8) Lists publications that are replacing AFR 127–1. | h. AFR 0–13. |
| ____ (9) Is a list of all forms used by the Air Force by type in numerical order. | i. |
| ____ (10) Lists the numbers of recurring periodicals. | j. AFR 0–16. |
| ____ (11) Has a list of safety standards you need in your shop. | k. AFR 0–17. |
| ____ (12) Lists current personnel tests. | |

4. Where can the title and numbers of TO categories be found?

5. Look at figure 1-12 and list the category number for an electrical drill press and an oxygen cylinder.

6. How are numerical type indexes unlike other type TO numbers?

7. What is the TO number for the alphabetical index?

8. State how TOs are identified and indexed.

9. What is the TO number of the first TO in the file?

10. How do we identify the contents in a TO binder?

11. How are TOs filed?

**021. Using an annotated page from AFR 0–2, determine which of the publications are in the file and which publications are on order.**

Operational units in the Air Force do not need to maintain complete files of all standard publications. Your own organization normally has in its file only the publications required to accomplish its mission. We must, then, have a system that allows us to check the status of the publications in the file.

**Index Annotation.** So that you will know whether or not your office files contain the publication you need, the file clerk uses a system of marking the organization's copy of AFR 0–2 in pencil or ink. Publications that you need and which are in the office file have a crossmark or plus sign (+) just ahead of the number in the index listing. If a publication is needed but not in the files, there is a minus sign (−) entered. This sign means that the publication is on order. If there is no mark next to the number, the publication is not in the file and it is not needed.

**Exercises (021):**

1. Use figure 1-10 and list the number of each publication shown to be in the file.

2. Use figure 1-10 and list the number of each publication shown to be on order.

**022. From a list of TO deficiencies, decide which ones are reportable and which ones are not.**

A TO improvement report is a suggested correction of an error or correction of terminology which affects the meaning of the information. It may also be to correct wrong information that will affect mission accomplishment. It could be used to suggest a better way of doing one of the tasks.

**Reportable TO Deficiencies.** The correction of minor inaccuracies of a nontechnical nature are not considered improvements and should not be reported. Technical Order

00–5–1, *AF Technical Order System*, explains in detail the procedures for reporting improvements in TOs. There are two forms available for reporting deficiencies: AFTO Form 22 and AF Form 847. AF Form 847, "Recommendation for Change of Publication," is used only for reporting deficiencies in flight and standardization manuals. Therefore, you are concerned with AFTO Form 22, "Technical Order System Publication Improvement Report and Reply."

Prior to submitting an improvement report, give some thought to the suspected deficiency in terms of what its effect will be on organizational mission, personnel safety, cost involved to change the TO, damage to equipment, work simplification, manpower savings, and urgency of the change. Three types of reports may be submitted, depending on what is involved and how critical it is. Submit these reports through your supervisor to the BCE quality control section. Types of reports will be covered under the next objective.

**Exercises (022):**

1. Indicate which of the following examples of technical order deficiencies should be reported by putting an X in the blank.

____ a. A tolerance that should read .050 instead of
____ b. Change the name of a switch used on a transfer panel.
____ c. The word blade being misspelled as "bade".
____ d. A critical adjustment that should read 1/4 turn instead of 1 1/4 turns.
____ e. A scaffold erection procedure that could cause the scaffold to collapse.

**023. Distinguish between the three types of publication improvement reports.**

**Publication Improvement Reports.** There are three types of publication improvement reports submitted on AFTO Form 22. They are emergency reports, urgent reports, and routine reports.

*Emergency reports/critical safety hazard reports*. These reports suggest improvements in TOs involving safety which, if not made, could result in fatal or serious injury to personnel, damage, or destruction of equipment or property, or failure to achieve or maintain an operational posture. These reports require AFLC to take action within 48 hours after the report is received. Emergency reports are sent by electrical transmission.

*Urgent reports*. These reports suggest nonemergency improvements involving a potentially hazardous condition. When a deficiency exists that could result in injury to personnel, damage to equipment or property, or jeopardize the safety or success of procedures, submit an urgent report. An urgent report requires action by AFLC within 40 days after receipt.

*Routine reports*. These reports, as shown in figure 1-15, describe improvements in TOs which, if not made, could result in a hazardous condition through prolonged use or have a negative effect on operational efficiency. Another use for this report is for a TO deficiency which can reduce the operational life or general service of a piece of equipment. Replies to routine reports are required within 60 days and corrective action within 240 days.

**Exercises (023):**

1. Fill in the blanks in front of the numbers of column A with either a, b, or c from column B that applies to the situation.

| *Column A* | *Column B* |
|---|---|
| ____ (1) Safety condition which could result in injury. | a. Emergency report. |
| ____ (2) Sent by electrical transmission. | b. Urgent report. |
| ____ (3) Safety condition could cause destruction. | c. Routine report. |
| ____ (4) TO deficiency affecting the operational efficiency. | |
| ____ (5) Corrective action to be taken within 48 hours. | |
| ____ (6) Safety improvement involving safety which could save a life. | |
| ____ (7) Hazardous condition could exist if used for a long period of time. | |
| ____ (8) TO improvement for condition which could reduce the operational life of a power transformer. | |
| ____ (9) Action taken in 40 days to correct deficiency. | |
| ____ (10) TO deficiency that could result in destruction of equipment. | |
| ____ (11) Require a reply within 60 days. | |
| ____ (12) Deficiency which could damage a line truck if not corrected. | |

**024. State how publications are filed, and list the procedures used to locate the publications in a file.**

**Locating Standard Publications.** When you consider the large number of Air Force publications required for operation, it is clear that there must be a filing system for these publications. This system is set up to help you find the publication, changes, and supplements you need. For this reason, you must know how the publications are filed in the file and within the binders.

*Filing method*. Standard publications are filed in standard three-ring binders in the order they appear in AFR 0–2. That is, the publications are filed in numerical sequence by subject series and specific item number. Each binder has a label which indicates the contents of the binder. The binders are then filed in a bookcase in numerical sequence, as shown in figure 1-16. Note that the

**TECHNICAL ORDER SYSTEM PUBLICATION IMPROVEMENT REPORT AND REPLY** — FORM APPROVED OMB NO. 21-R0267

| 1. TO: (Major Command or equivalent) | 2. TO: (Orgn having Mgmt Responsibility for the T.O.) | 3. FROM (Orgn reporting) | 4. REPORT DATE (YR MO DAY) |
|---|---|---|---|
| ATC/DEMU<br>Randolph AFB, TX 78148 | SM/ALC/MMEDT<br>McClellan AFB, CA 95652 | 3750 CES/DEME<br>Sheppard AFB, TX 76311 | 79 11 16 |

| 5. BASIC DATE OF T.O. | 6. DATE OF T.O. CHANGE | 7. PAGE NUMBER | 8. PARAGRAPH NUMBER | 9. FIGURE NUMBER |
|---|---|---|---|---|
| 1 Oct 1966 | Chg 8, 12 Aug 1974 | 4-7 | 4-12 | NA |

| DOC IDENT (1-3) | TO (4) | FROM (5) | TECHNICAL ORDER NUMBER (6-30) | IMPROVEMENT REPORT NUMBER (31-45) |
|---|---|---|---|---|
| XYA | H | | 35C2-3-398-1 | 2ØJ3750CES9Ø24R |

10. BRIEF SUMMARY OF DEFICIENCY AND RECOMMENDED CHANGE (Use continuation sheets if necessary)

This report concerns electrical safety during operation of a Generator Set, Diesel Engine, Type EMU-17/E. Paragraph 4-12 reads "DURING OPERATION. Check again for fuel leaks. Perform any inspections within generator set with great caution to avoid mechanical injury or dangerous electrical shock."

It is recommended that the following sentence be added to paragraph 4-12. "Insure that you remove all jewelry and secure or remove all loose clothing."

| 11. REPORTED BY (Initiator's Signature, OAS and Extension) | 12. APPROVED BY (Supervisor's Signature) | 13. QUALITY CONTROL (Signature) |
|---|---|---|
| Robert L. Willingham<br>Robert L. Willingham, SSgt<br>3750 CES/DEME/736-4340 | Thomas C. Little<br>Thomas C. Little, SMSgt<br>NCOIC, Electrical Sec. | John T. Jones<br>John T. Jones, Maj |

| 14. MAJOR COMMAND ACTION | 15. (Check applicable block) ☐ APPROVED ☐ DISAPPROVED | 16. SIGNATURE (Major Command Authority) | 17. DATE |
|---|---|---|---|
| | | | |

| ☐ | TR CODE (46-48) | DATE RECEIVED YR MO DAY (49-54) | DATE TO MGR YR MO DAY (55-60) | MCR (61) | TRANSFER CODE (62-66) | DOWN-GRADED (67) | (Reserved) (68-80) |
|---|---|---|---|---|---|---|---|
| | DAA | | | | | | |

| ☐ | TR CODE (46-48) | DATE FROM MGR YR MO DAY (49-54) | ACTION TAKEN (55-66) | RESOLUTION DATE YR MO DAY (67-72) | (Reserved) (73-80) |
|---|---|---|---|---|---|
| | DBA | | | | |

| 18. TO: (Major Command or equivalent) | 19. TO: (Organization Reporting Improvement) | 20. FROM (SM/IM) |
|---|---|---|
| | | |

21. REMARKS (Use continuation sheets if necessary)

| 22. DATE OF REPLY | 23. REPLY BY (Signature, OAS, Extension) | 24. APPROVED BY (Supervisor) |
|---|---|---|
| | | |

AFTO FORM APR 73 22 — REPLACES AFTO FORMS 22 AND 22A WHICH ARE OBSOLETE

Figure 1-15. Completed AFTO Form 22.

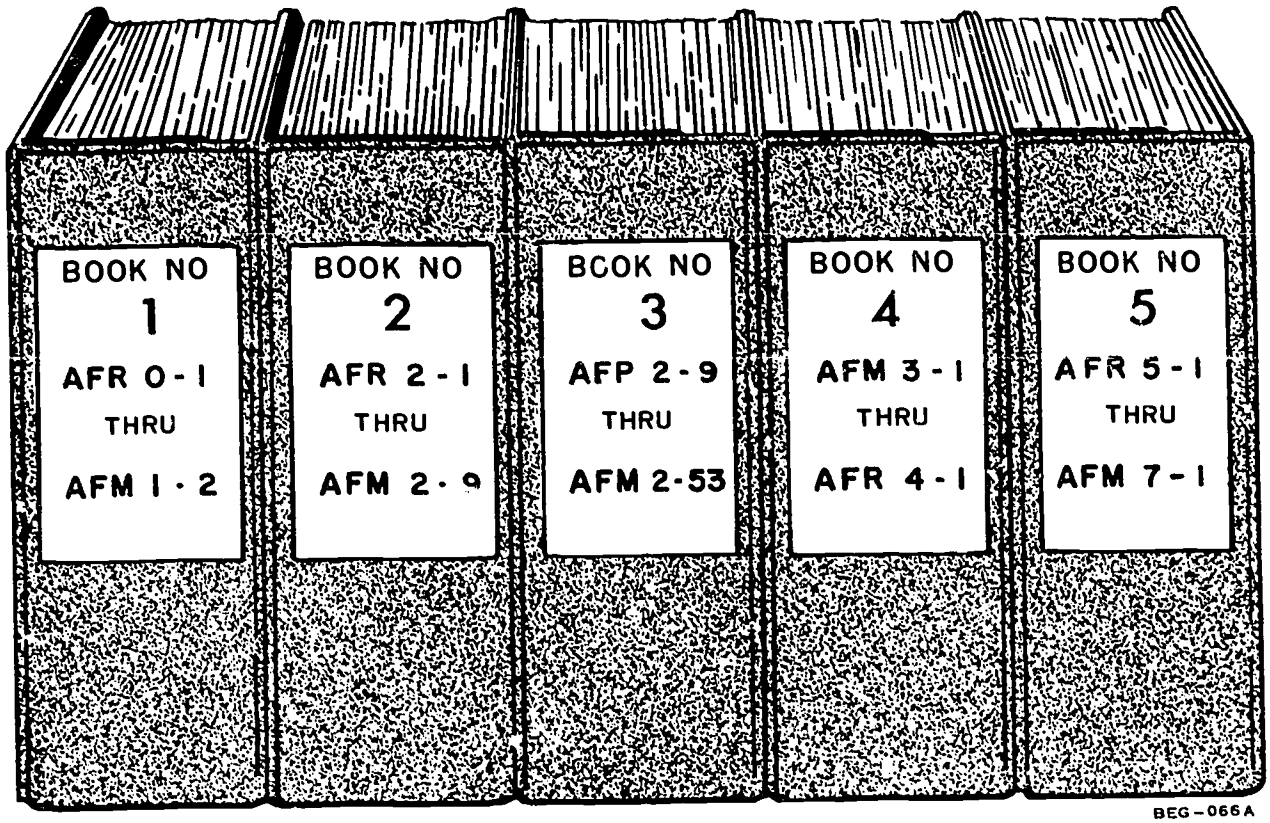


Figure 1-16. Standard publication binders.

binders are also numbered 1, 2, 3, 4, etc. These numbers will readily indicate when binders are missing or out of proper sequence.

*Current status.* Publication files are kept current by changes, supplements, and revisions. Changes are filed immediately behind the publication affected. Supplements are filed in descending order according to the level of command that published the supplement. Figure 1-17 shows the proper sequence to put changes and supplements in a file. Revisions are complete new editions, and replace or supersede the original publication.

*Locating publications.* Since there may be several binders and several dozen publications in the file, you must know the exact number assigned to the publication you need. Your first step locate a publication, then, is to identify the number of the needed publication. You identify this number by using the alphabetically listed subjects in the front of AFR 0–2. This index is in the first book of the file. Once you locate the proper subject series number, you can turn to that series number in the index and locate the desired publication by title and number. Next, you check the current status and availability of the publication. Your next step is to locate the actual publication in the file. Look at the numbers on the inserts on the back of the binders. When the number appears on the insert or falls between the numbers on the insert, your publication is in that binder.

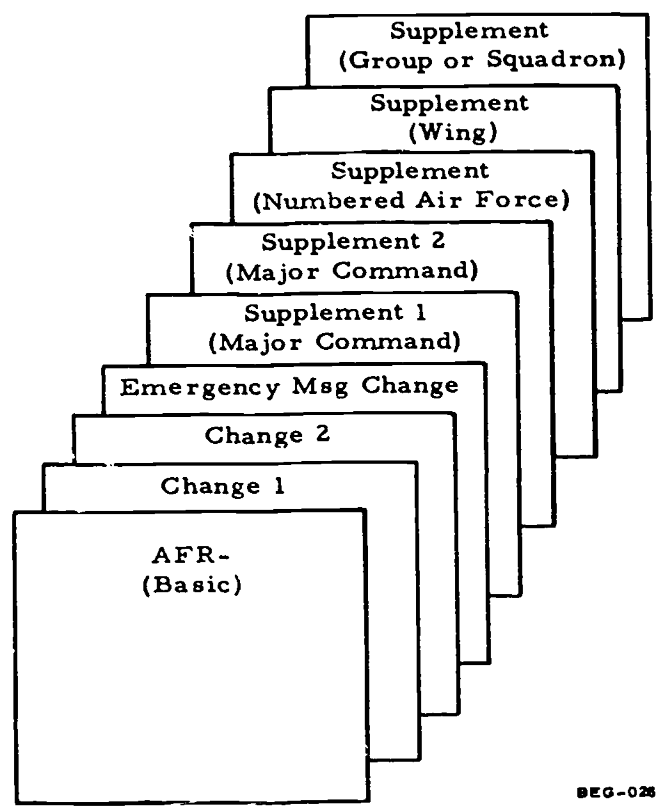


Figure 1-17. Filing changes and supplements.

When you know the title and number of a publication, you must still check AFR 0–2 to see if the organization has a current copy with changes.

**Locating TOs.** Certain steps will help you to find TOs in a TO file. As you know, the first binder or binders in the file will contain a copy of all the numerical indexes that apply to the publications in the file. The remaining binders contain the TOs that make up the files. These TOs are limited to those that apply to your operations. Now, assume that you need information about a special tool. Your first step is to check 0–1–01 for the category index covering special tools. This index is 0–1–32. Your second step is to locate the binder that has the index 0–1–32. Next, look in the table of contents in TO 0–1–32 to find the subcategory under which the type of tool is listed. Then, turn to this subcategory and locate the specific TO number. Let us say that the TO you need is 32B10–2–16–1. You find the binder by looking at the tabs until the TO number matches or falls between the numbers on the tab. Finally, remove this binder from the file and turn to the TO that contains the information you need.

**Exercises (024):**

1. Briefly state the filing method for standard publications.

2. Give the filing sequence for changes and supplements.

3. Look at figure 1-11 and list the binder number that would contain publication AFM 3–21.

4. List the procedures used to locate standard publications in a file.

5. State the procedural steps used to locate TOs in a file.

6. Look at figure 1-14 and record the binder number that would contain TO 34Y1–42–12–1.

**025. List the procedures used to locate information in publications.**

**Methods of Locating Information.** The methods of locating information in any publication must be fast, easy, and efficient. Once you find the publication you want in the file, locate the subject matter that you are interested in by referring to the table of contents in the front of the publication or the index in the back. The table of contents contains chapter or section headings and topics of a broad scope. The index is an alphabetical listing of specific subjects. The index is probably the best place to find the title of the subject that you are looking for. Using either reference gives a location in the publication to which you should refer for information on the subject.

After you find the subject in the table of contents or the index, you will be able to find the page or paragraph where you can research for information about the subject. The pages are numbered in various ways. Some publications have the pages numbered in numerical order, such as 1, 2, 3, 4, etc. Some are numbered by the chapter and then the page, such as 2-4, which means chapter 2, page 4. In this case, each chapter starts with page 1. Other publications are numbered by the chapter and paragraph, such as 4-25, which means chapter 4, paragraph 25. In this case, each chapter starts with paragraph 1. At this point, all that is left for you to do is to turn to the proper chapter or page number, find the paragraph, and read.

**Exercises (025):**

1. List two methods of locating subjects in publications.

2. What advantage does the use of the index afford over that of the use of the table of contents?

3. List the procedures to follow to find specific information on a subject in a publication.

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# Resource Management

THE MANAGEMENT philosophy of the Air Force includes getting maximum efficiency for each dollar spent while attaining planned objectives. This means that human resources must be consumed in the most effective way to meet the goals of the organization. As you supervise electrical jobs on your base, you should ask and answer these two questions: "Are the jobs being done well?" and "Is there a way to do them better?"

The key to improving jobs is not necessarily an attempt to speed up work by prodding your workers. Substandard work may be brought up to standard by better project planning, improving material support, and eliminating delays. Your coordination with the equipment shop might save many man-hours of standby time. Man-hours that are not consumed by productive work are a waste of Air Force dollars. So plan your projects well—that is, with resource management in mind.

## 2-1. Work Authorization Documents

To be an effective supervisor, you must be able to use manpower effectively. Before any work can be done by your shop, it must be authorized on some kind of "Work Authorization Document." In this section we will cover these documents.

**026. State the basic concepts of the civil engineering management system.**

**CE Management System.** You may ask the question, "Who originates all the work that my shop has to do?" The great majority of the work in civil engineering has been identified and planned ahead of time. The planning and controlling of this work could not be done without a sound management plan. The plan we are talking about is called the *Inservice Work Plan (IWP)*. This plan, like all other plans, is only as good as the information that is used for its development and the effort that is put forth to adhere to the principles and objectives of the plan.

*Planning*. Do you recall earlier an office called Resources and Requirements? Under this office is a unit known as "planning." Each year the planners visit each facility on base and thoroughly inspect it for any work that needs to be done. The inspection is called a *facility survey*. This survey is one of the inputs required by civil engineering to develop its work plan.

In addition to the facility survey, shop supervisors are responsible for two inputs to the work plan. One of them is for "recurring" labor hours, and the other is for "equipment maintenance" labor hours such as fire alarms. The recurring labor hours are for work done on a periodic basis within a particular year. An example of this work is cathodic protection readings. Another example would be relamping hangars.

After all the work inputs are sent to Production Control, the IWP programmer gathers them together and places the labor hours on a document called the IWP./n IWP. Each month work items from this plan are sent to the work control scheduling section for assignment to CE shops. These work items come on forms known as "work authorization documents." As the words indicate, these documents are the authority from civil engineering to perform the work stated on the forms.

*Performance evaluation*. Civil engineering also has a management plan. In this plan there are provisions for evaluating the performance of CE units. Using the "management by exception" technique, which compares the "estimated" versus the "actual" labor hours, industrial engineering can evaluate the performance of operations cost centers. Frequent deviations from the estimated labor hours will signal the need for further in-depth evaluations.

*Base engineer automated management system (BEAMS)*. In civil engineering a large number of records need to be kept. These records include the amount and cost of electricity consumed on base; amount of sewage disposed; labor hours required to operate power plants; size, shape, condition, and cost of each facility. Many other records are required by law to be kept. Even your name and employee number are part of the records. When information of this sort is needed, civil engineering merely asks the computer in symbols and it will furnish this information. In a matter of seconds the computer replies with up-to-date answers.

The name used to identify the automated data processing system is BEAMS. The computer used is the Burroughs 3500 (B3500). BEAMS provides a means of automating a large number of civil engineering records and files. It is of great significance that these files can be maintained with efficiency and effectiveness within the automated system; however, it is of even greater significance that they provide the information for a great variety of computer products that are available to managers on demand. These products can be, and are, used by managers to make many important decisions. Actions of most all shop workers within civil engineering affect the information within the computer files and records and ultimately influence the content of the management products. These influences are either direct as

are the actions of personnel who maintain cost, real property, work control, and programming records files, or indirect as are the actions of shop workers who report the labor hours and materials used to accomplish an assigned job. It is of utmost importance that all civil engineering personnel know that their actions directly or indirectly influence the accuracy of the information contained in the automated system and consequently the management products that the system produces. The reliability of their contribution builds their own faith in BEAMS and the decisions of those who use it.

**Exercises (026):**

1. What is the Inservice Work Plan?

2. Who performs a facilities survey and what is it?

3. Name two inputs you as a shop supervisor of the interior electrical shop, would make to the work plan and give an example of each.

4. What is management by exception?

5. What is the name of the automated computer system used to process civil engineering records?

**027. Identify forms, rationales, and examples of work related to the Recurring Maintenance Program.**

**Recurring Maintenance Program (RMP).** Recurring work is made up of the RMP, the operations and services work program, and other recurring work for which the scope and level of work is known without a prior visit to the job site each time the work is scheduled. The BEAMS RMP is an automated schedule for work to be done. The RMP schedule is filled out by the shop supervisor and sent to the superintendent for approval. Examples and instructions on how to fill it out are found in Chapter 10 of AFR 85–1, *Resources and Work Force Management*.

Recurring maintenance applies only to equipment and real property maintained by BCE. The procedures are as follows:

*a*. Items included in the RMP are limited to items whose scope and frequency requirements are known and must be done at least once a year but not daily.

*b*. Items with a replacement cost of less than $250 are not included unless failure seriously impacts the mission or results in damage to high value items.

*c*. Superintendents must approve all items included in the RMP.

*d*. The RMP program in the BEAMS is used to maintain an inventory, schedule tasks, and report completion of the RMP work. Production control loads RMP data into the BEAMS files.

*e*. An Air Force Form 1841, Maintenance Action Sheet (MAS), is used to identify maintenance actions. An example of a MAS is shown in figure 2-1. A master copy of your shop MAS is kept in production control for audit purposes.

*f*. The superintendent reviews the shop's RMP items periodically to make sure only essential work is included.

Some of the work in the electrical career field could fall under the RMP. Some examples are listed below:

*a*. Calibrating thermostats on deep-fat fryers.
*b*. maintaining emergency lights.
*c*. Reading static grounds.
*d*. Reading lightning protection.
*e*. Cathodic protection maintenance.
*f*. Fire alarm maintenance.
*g*. Intrusion alarm maintenance.

Items that are not included in the RMP are:

*a*. Equipment items maintained by contract services and equipment items maintained or checked daily.

*b*. Equipment items used daily by operators. Bases can include equipment items that have manufacturer-suggested maintenance tasks, or those equipment items that pose potential fire or safety hazards.

*c*. Items of equipment that are more economical to maintain and repair on an as required basis.

*d*. RPIE (Real Property Installed Equipment) items related to missile facilities when maintenance procedures are established by the command.

*e*. Appliances.

*f*. Operations and services work items.

**Exercises (027):**

1. What is the Recurring Maintenance Program (RMP).

2. What AF Form is used to identify maintenance actions and who fills it out?

3. Who reviews the shop's RMP items and for what reason?

4. List three examples of work in the electrician career field that falls under the recurring maintenance program.

Figure 2-1. AF Form 1841.

| MAINTENANCE ACTION SHEET | COST CENTER 471 | DESCRIPTION 01029 Fire Station Door | MAS NUMBER 0001 |
|---|---|---|---|

| REQUIRED MAINTENANCE ACTIONS | REFERENCE | STANDARD HOURS | FREQ. | CREW SIZE | HEAVY EQP |
|---|---|---|---|---|---|
| 1. Bearing housing, check for vibration and noise, properly seated seals and hand test for temperature. Operate doors. | AFM 91-17 7.1.3. | 2 | M | 2 | 2 |
| 2. Check all lubricating fittings - 4 ea - for; tight, serviceable repair or replace damaged or missing fittings. | 7.1.3. | 4 | Q | 2 | |
| 3. Lubricate bearings with special ball and roller bearing grease. | | | | | |
| 4. Check chain drive for tension, adjust to manufacturer's recommendation, adjust guards and housings. | 7.1.3 | 10 | S | 2 | |
| 5. Check alinement of motor and drive apparatus adjust as necessary. | | | | | |
| 6. Check motor end play, and shaft axial float. | | | | | |
| 7. Clean roller bearings in solvent re-pack. | 7.1.3 | 16 | A | 2 | |
| 8. Clean and inspect rotor, bars and fan blades. | | | | | |
| 9. Measure insulation resistance, be sure windings are dry. | | | | | |

| DATE | WCF INITIALS | DATE | SUPERINTENDENTS INITIALS |
|---|---|---|---|
| | | | |

AF FORM JUL 72 1841

**028. State the purpose of man-hour accounting and methods of time accounting.**

**Man-Hour Accounting.** Effective manpower planning and programming depends upon having complete man-hour data. A man-hour accounting system is designed to provide a uniform reporting method of maximum accuracy with minimum effort and cost. Man-hour accounting provides CE management and base accounting and finance with direct labor costs against work order numbers. It also provides CE management personnel with information that will allow them to direct and control manpower resources. There are two methods of time accounting: the actual time accounting (ATA) system and the exception time accounting (ETA) method. Each BCE shop will use one method or the other to report labor.

**Exercises (028):**

1. What are the two purposes of man-hour accounting?

2. What are the two methods of time accounting?

OB 029. State how AF Form 1734 is used in the ATA system, and give the correct procedures to record man-hours expended.

**Actual Time Accounting.** Cost centers (shops) of BCE using ATA will report the total number of direct hours expended against each work order number by "labor utilization code (LUC)" and the total number of indirect hours charged to another LUC. The interior electric shop comes under the ATA system. Air Force Form 1734, BCE Daily Work Schedule, is used by actual time accounting cost centers (shops) to record man-hours. An example is shown in figure 2-2. The shop supervisor or controller will enter the following information on AF Form 1734 daily:

*a*. Enter the date that labor is to be performed at the top of the form in the space provided.

*b*. Enter the names of individuals being borrowed from another shop and those assigned to that shop but not already listed on AF Form 1734. Handprint them below the first group of names (military personnel) if they are military and below the second group (civilian personnel) if they are civilians.

*c*. If an individual is being loaned to another shop, enter the control center code and cost center code of the gaining shop on the AF Form 1734.

*d*. Note that if an individual is borrowed from another shop, the loaning control center code and cost center code are not entered on the form. The person will be reported as loaned by their shop supervisor.

*e*. Enter the names of personnel being loaned and/or borrowed between subcost centers within the same cost center and not reported as loaned or borrowed. Their names will be charged to the work order number against which it was expended.

*f*. Always report borrowed and loaned labor when a change of cost center is involved.

*g*. If an individual is assigned to the cost center or subcost center but does not appear on the appropriate AF Form 1734, the administration section will be contacted to make corrections of the situation.

The AF Form 1734 is filled out each day for each shop by the controller or shop supervisor. It is based on an AF Form 561, Base Civil Engineering Weekly Schedule and decisions made by the supervisor and shows the location or status of each worker.

The shop supervisor makes job assignments to all the workers for the next day and notifies the controller to post the AF Form 1734. The supervisor assigns each worker a day's work and gives the worker the necessary maintenance action sheets, work orders, and job orders. The controller then marks a job sequence number on the daily work schedule for each job assigned to a worker beginning with 1 (first job). The next sequence number shows the sequence of work for each worker. No man-hours, in a block following a block with man-hours noted, indicates a current job assignment for that worker. The supervisor also tells the controller what workers are not there due to sickness, emergency, and so on, so that entries can be made to the daily work sheet.

The workers tell the controller when they finish each job and how many man-hours were used. When more than one worker is involved, the assigned working leader reports the manhours each worker used. The workers also tell the controller when they leave the job site. The controller verifies the next job with the worker, arranges for transportation, and notifies the next customer.

The man-hours are entered on the work sheet by job order, RMP, work order, and do-it-now (DIN) numbers. At the end of the day, the controller or supervisor will compute the manhours used and completes the work sheet. Follow instructions given in chapter 14 of AFR 85-1.

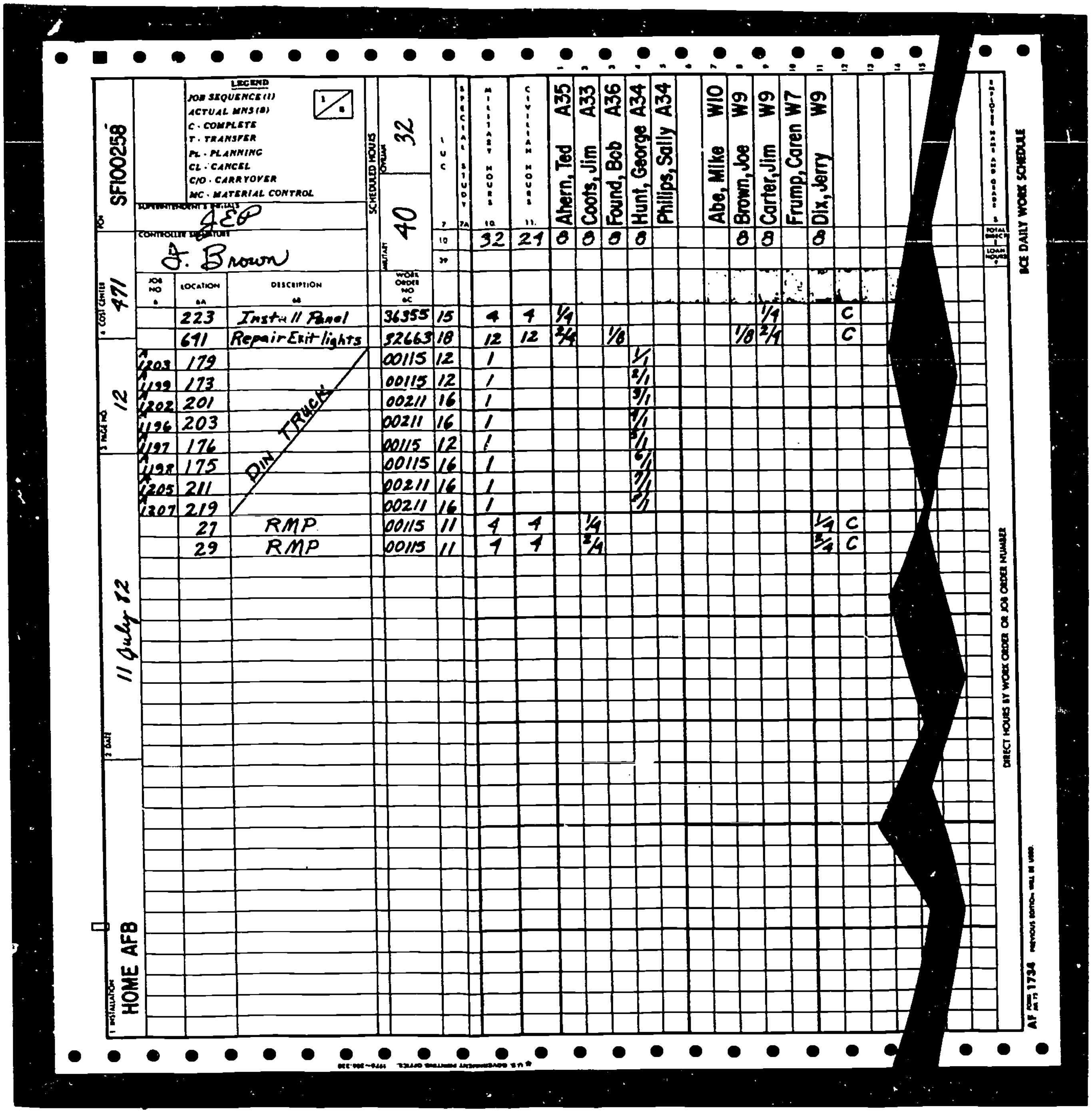
**Exercises (029):**

1. What is AF Form 1734, BCE Daily Work Schedule, used for and who fills it out?

2. Where are the names of personnel loaned to your shop entered on the daily work sheet?

3. What is entered with a loaned individual's name?

4. What are the entries on the daily work sheet based on?



LEGEND
JOB SEQUENCE (1)
ACTUAL MHS (8)
C - COMPLETE
T - TRANSFER
PL - PLANNING
CL - CANCEL
C/O - CARRYOVER
MC - MATERIAL CONTROL

1 INSTALLATION: HOME AFB
2 DATE: 11 July 72
3 PAGE NO: 12
4 COST CENTER: 471
FOI: SF100258
SUPERINTENDENT'S INITIALS: JEP
CONTROLLER SIGNATURE: J. Brown
SCHEDULED HOURS: OVERALL 32, MILITARY 40

| Job No | Location | Description | Work Order No | UC | Military Hours | Civilian Hours | Ahern, Ted A35 | Coots, Jim A33 | Found, Bob A36 | Hunt, George A34 | Phillips, Sally A34 | Abe, Mike W10 | Brown, Joe W9 | Carter, Jim W9 | Frump, Caren W7 | Dix, Jerry W9 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 32 | 21 | 8 | 8 | 8 | 8 | | | 8 | 8 | | 8 | |
| | 223 | Install Panel | 36355 | 15 | 4 | 4 | 1/4 | | | | | | | 1/4 | | | C |
| | 641 | Repair Exit lights | 32663 | 18 | 12 | 12 | 3/4 | | 1/8 | | | | 1/8 | 2/4 | | | C |
| 1203 | 179 | DIN TRUCK | 00115 | 12 | 1 | | | | | 1/1 | | | | | | | |
| 1199 | 173 | | 00115 | 12 | 1 | | | | | 2/1 | | | | | | | |
| 1202 | 201 | | 00211 | 16 | 1 | | | | | 3/1 | | | | | | | |
| 1196 | 203 | | 00211 | 16 | 1 | | | | | 4/1 | | | | | | | |
| 1197 | 176 | | 00115 | 12 | 1 | | | | | 5/1 | | | | | | | |
| 1198 | 175 | | 00115 | 16 | 1 | | | | | 6/1 | | | | | | | |
| 1205 | 211 | | 00211 | 16 | 1 | | | | | 7/1 | | | | | | | |
| 1207 | 219 | | 00211 | 16 | 1 | | | | | 8/1 | | | | | | | |
| | 27 | RMP | 00115 | 11 | 4 | 4 | | 1/4 | | | | | | | | 1/4 | C |
| | 29 | RMP | 00115 | 11 | 4 | 4 | | 3/4 | | | | | | | | 3/4 | C |

DIRECT HOURS BY WORK ORDER OR JOB ORDER NUMBER

BCE DAILY WORK SCHEDULE

AF FORM 1734 PREVIOUS EDITION WILL BE USED.

Figure 2–2. AF Form 1734.

5. What is indicated by no man-hours shown on the daily work sheet following a block where man-hours are noted?

6. How are the man-hours for each job entered on the work sheet?

**030. Tell how and what is recorded when the ETA system is used, and identify ETA cost centers.**

Another system that is used in conjunction with the ATA man-hour accounting system is the ETA system.

**ETA Cost Centers.** A monthly BEAMS program computes labor cost for ETA cost centers. Direct (normal duty) and indirect (exception time) are not reported by ETA cost centers except for loaned labor between ETA and ATA cost centers. Loaned labor is not reported when done for ETA to ETA cost centers, except for family housing management. Examples of ETA cost centers are work control, planning, real estate management, cost accounting, engineering, and others like these.

**Exercises (030):**

1. How is the exception time accounting (ETA) system used?

2. What labor must be reported?

3. What cost centers use the ETA system?

**Identify the type of work order used in a given job situation and give the document and procedure used to schedule the work order.**

The BCE organization must have a way of documenting its time and coordinating the work it accomplishes. Through the use of various types of work orders and a weekly schedule, the supervisors of all the CE shops can do the work that needs to be done in a fast and efficient manner.

**Job Orders.** The job order system is a fast way to authorize work that does not require detailed planning. The system includes emergency, urgent, routine, structural maintenance and repair team (SMART), and military family housing (MFH) renovation job orders.

*Routine job orders:* This is work that should be done within 30 calendar days after identification of the requirement or receipt of material but does not qualify as emergency or urgent work. A routine job order is authorized on Air Force Form 1879. See figure 2-3.

*Structural Maintenance and Repair Team (SMART).* This is the most economical way to do minor maintenance and repair work in high use facilities. It uses a team of workers with various skills. The team normally works out of a trailer. Work is identified by the SMART supervisor or a designated SMART worker on an Air Force Form 1219, shown in figure 2-4.

*Military family housing renovation.* MFH renovation job orders authorize work on MFH units during a change of occupancy. The work is authorized on Air Force Form 1219 and is done by a multicraft work crew.

**Service Call.** Emergency and urgent job orders are managed by the service call function. This work is normally received by telephone. Workers in radio-controlled DIN trucks are dispatched by a service call specialist to the job site. DIN trucks are normally multi-stop vehicles equipped with tools and materials to handle most emergency and urgent job orders. After the job is finished, the workers radio the service call specialist for follow-on assignments. Response to verbal requests is based on the nature of the work.

If the work cannot be done by the DIN workers, then the call will be assigned to the shop and should be accomplished as soon as possible.

*Emergency job order.* Any work required to correct an emergency condition that is detrimental to the mission or reduces operational effectiveness, is an emergency job order. It includes providing security to areas subject to compromise, eliminating hazards to health, or protecting high value property and equipment. An emergency includes, but is not limited to, the failure of any utility, fire protection, environmental control, security alarm system, stopped-up sewage, and fire hazards.

*Urgent job order:* This is work that is not an emergency but that should be done in 5 workdays.

**Work Orders.** Work that requires detailed planning is authorized on Air Force Form 327, shown in figure 2-5. It is a way to control large or complex jobs. The decision to use a work order is based on the need for:

- Detailed planning.
- Capitalization of real property records.
- Collecting reimbursements.
- Gathering data for review and analysis.

Work that does not need detailed planning, special costing, close coordination between shops, or large bills of material is usually authorized on a job order.

**BCE Weekly Work Schedule, Air Force Form 561.** Each week, production control develops a schedule on Air Force Form 561 for each shop to include work orders on the IWP charts; man-hours required for emergency, urgent, and routine job orders; and items identified in the recurring work program.

Daily work scheduling is managed by shop supervisors through the controller under the supervision of the superintendents. Work selected by shop supervisors from

| FACILITY NO. | ACTIVITY OR STREET ADDRESS | DATE | TIME | JOB ORDER NO. |
|---|---|---|---|---|
| 1117 | TEST PAD | 7 JUNE 81 | 1120 | 3-2215 |

| NAME AND GRADE OF REQUESTOR | PHONE NO./ALTERNATE | COLLECTION WORK ORDER NO. |
|---|---|---|
| MSgt. Phillip | 2216/2219 | |

SERVICE REQUIRED

REPAIR EMERGENCY LIGHT, NE CORNER OF CONTROL CAB

ZONE NO. 5

| TYPE OF SERVICE | | | |
|---|---|---|---|
| | EMERGENCY | | SMART |
| | URGENT | | MFH |
| X | ROUTINE | | MC |

ESTIMATED COMPLETION DATE: 21 JUNE 81

INDICATE WHEN WORK IS TO BE ACCOMPLISHED

CREW SIZE

EST TOTAL TIME

AREA/FACILITY WHERE JOB IS LOCATED

REMARKS (Tools, equip, materials, special craftsman multi-shop notes, etc.)

1 ea 12 Volt Jell-cell battery, Verta-Ray PN-6-P-12VAC

6 ft. 12/2 WG CORD

6 ft. Stepladder

DANGEROUS CONDITIONS EXISTING (if any): NOISE HAZARD

RESTRICTIONS (time, entry, security)

| MAKE OF EQUIPMENT | TYPE/SIZE OF ITEM | COLOR OF ITEM |
|---|---|---|
| VERTA RAY | 2 HEAD EMERG/LIGHT | N/A |

| ASSIGNED TO | DATE | TIME | COMPLETED BY | DATE | TIME | INITIALS | LUC 12 | LUC |
|---|---|---|---|---|---|---|---|---|
| 471 | 19 JUNE | 0700 | ANN SMITH | 19 JUNE | 0900 | JEP | | 2 HRS |

| REFERRED TO | DATE | TIME | COMPLETED BY | DATE | TIME | INITIALS | LUC 12 | LUC |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

| DEFERRED TO | DATE | TIME | DISPOSITION | AUTHORIZED |
|---|---|---|---|---|
| | | | | |

AF FORM MAY 78 1879 PREVIOUS EDITION IS OBSOLETE. SHOP COPY BCE JOB ORDER RECORD

Figure 2-3. AF Form 1879.

**BCE MULTI-CRAFT JOB ORDER**

| JOB ORDER NO. | |
|---|---|
| COST CENTER | 457 |
| COLLECTION WORK ORDER NO. | 06245 |
| FACILITY NO. | 1200 |
| DATE PREPARED | 26 JUNE 81 |
| NAME OF INSPECTOR | POTTS, J. SSgt. |
| USING AGENCY | 26 FMS |
| INDIVIDUAL TO CONTACT (Name & Phone No.) | POTTS, SSgt. 2230/2259 |

Job order no.: MO-26

| WORK DESCRIPTION | LOCATION | MATERIALS ITEM | QNTY | UM | M/HR. EST. | CRAFT | INCOMPLETE WORK |
|---|---|---|---|---|---|---|---|
| REPL WINDOW | EAST SIDE | 48" X 48" | 1 | EA | 2 | CARP | |
| REPL SINK | Latrine | SINK | 1 | EA | 2 | PLUMB | |
| REPAIR EX. LIGHTS | E. HALLWAY | EXIT LIGHT | 1 | EA | 1 | Int. Elect | |

AF FORM MAY 74 1219 PREVIOUS EDITION IS OBSOLETE.

| WORK DESCRIPTION | LOCATION | MATERIALS ITEM | QNTY | UM | M/HR EST. | CRAFT | INCOMPLETE WORK |
|---|---|---|---|---|---|---|---|

| TOTAL ESTIMATED MAN HOURS | CARP. | PLUMB. | ELEC. | PAINT. | OTHER | | | | TOTAL | TOTAL ACT. HRS |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 2 | 1 | | | | | | 5 hrs. | |

REMARKS

SIGNATURE OF INSPECTOR: SSgt. JERRY POTTS

| DATE ASSIGNED | AUTHORIZING SIGNATURE |
|---|---|
| 21 JULY 81 | Robert F. Horse |
| **DATE COMPLETED** | **SUPERVISORS SIGNATURE** |
| 9 AUG. 81 | Robert F. Horse |

Figure 2-4. AF Form 1219.

| 1. INSTALLATION NAME | 2. WORK REQUEST NO. | 3. PROJECT NO. | 4. REQUESTER'S NAME AND PHONE NO. | 5. CHANGE ORDER NO. | 6. LUC | 7. WORK ORDER NO. |
|---|---|---|---|---|---|---|
| A. CONTROL Sheppard AFB, Tx<br>B. OTHER Reese AFB, Tx. | 4540 | | Col. Robert Fisk. | | 15 | A-2221 |

**8. STATEMENT OF WORK**

Replace the main panel in the building.

**13. AUTHORIZATION**
A. SIGNATURE CHIEF OF RESOURCES
B. DATE 27 May 81

**14. COMPLETION**
A. SIG OF COST CENTER SUPVR Supervisor
B. COST CENTER NAME 471 INTERIOR ELECTRIC
C. ACTUAL COMPLETION DATE

15. TOTAL ESTIMATED COST Planning

**9. WORK ORDER MASTER FILE** *(Remote Input Format) (Card Columns 1 – 108)*

| TRANSACTION IDENTIFIER 1-7 | 8 | CONTROL INSTL 9-12 | CC 13 | WORK ORDER NO. 14-18 | 19 | TN 20 | WI 21 | NR SH 22-23 | INSTL INDICATOR 24-27 | WC 28 | RRI 29-30 | FACILITY I.D. NO. 31-35 | FAC SUF 36-37 | COST ACCOUNT 38-42 | PR 43 | CI 44 | GQ 45 | WORK DESCRIPTION 46-75 | SI 76 | ORG CODE 77-79 | TI 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WCM-ADD | . | REES | B | 10338 | , | A | 0 | 1 | WQRO | C | EE | 00216 | | 51035 | 2 | | | Replace main panel | | 471 | |

| 9. CONTINUATION OF REMOTE INPUT FORMAT | | | | 10. INPUT FORMAT WHEN USING PSEUDO REMOTE | CARD COLUMNS 1-80—USE FORMAT ABOVE FOR TRANSACTION NO. 1<br>CARD COLUMNS 1-45—USE FORMAT BELOW FOR TRANSACTION NO. 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| WO OPENING DATE 81-86 | EST. START DATE 87-92 | EST. COMP. DATE 93-98 | EST. NON-AF EXCESS MAT. 99-105 | REPEAT CARD COLUMNS 1 - 19 ABOVE 1 - 19 | TN 20 | WO OPENING DATE 21-26 | EST. START DATE 27-32 | EST. COMP DATE 33-38 | EST. NON-AF EXCESS MAT. 39-45 | BLANK 46-80 |
| | | | | | 2 | | | | | |

**11. WORK ORDER SHOP FILE** *(Remote/Pseudo Remote Input Format)*

| TRANSACTION IDENTIFIER 1-7 | 8 | CONTROL INSTL 9-12 | C C 13 | WORK ORDER NO. 14-18 | COST CENTER 19-21 | 22 | NO. REQUIRED 23-25 | ESTIMATED LABOR HRS. 26-30 | ESTIMATED SHOP RATE COST 31-37 | ESTIMATED DIRECT MATERIAL COST 38-46 | ESTIMATED PROJECT CONTRACT COST 47-55 | ESTIMATED SERVICES CONTRACT COST 56-64 | ESTIMATED OTHER COST 65-73 | BLANK 74+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WCN-ADD | . | REES | B | 10338 | 471 | . | 009 | 1160 | | | | | | |
| WCN-ADD | . | | | | | | | | | | | | | |
| WCN-ADD | . | | | | | | | | | | | | | |
| WCN-ADD | . | | | | | | | | | | | | | |
| WCN-ADD | . | | | | | | | | | | | | | |
| WCN-ADD | . | | | | | | | | | | | | | |
| WCN-ADD | . | | | | | | | | | | | | | |
| 12 TOTAL | | | | | | | | | | | | | | |

AF FORM 327 JAN 76 PREVIOUS EDITION WILL BE USED BASE CIVIL ENGINEER WORK ORDER

Figure 2-5. AF Form 327.

Air Force Form 561 is released to workers and logged by controllers. Based on decisions of the supervisors, controllers sequence follow-on work assignments and relay instructions to the workers. The objective is to know the location of each worker and the status of all work. You may be called on to work with the scheduler in filling out a 561, therefore you should be familiar with this form. An example of this form is shown in figure 2-6.

**Exercises (031):**

1. In the space provided, state the type work order required for each of the following job situations.

   a. No power to computer center.

   b. Porch-light inoperative in family housing.

   c. Install indirect lighting in the commander's office.

   d. Assist a SMART team by replacing a broken receptacle cover.

2. Who manages AF Form 561, BCE Weekly Work Schedule?

3. State the objective of AF Form 561.

## 2-2. Property Accountability and Responsibility

It is important that you understand your responsibility for Government property. If you are careless when placed in charge of Air Force property you may pay for a piece of equipment for which you damaged or lost. Your knowledge of the rules and procedures will make you conscious of your responsibility for government property.

**032. Associate the type of property responsibility, liability, or form with the appropriate identifying statements.**

**Property Accountability and Responsibility.** The organizational commander is responsible and accountable for all property that is issued to his organization, whether he signs for it or not. But because the duties of the commander make it impracticable for him to exercise personal supervision of the supply functions, a commander designates an officer to act as his supply officer. The commander or his supply officer may then name other representatives to receive and sign for property in his name. However, delegation of duty does not make the commander exempt from financial liability for loss, damage, or destruction of property.

Property responsibility means that each one of us is obligated to take care of Air Force property, whether it has been issued to us or to our unit. This will include pecuniary liability.

When you buy an article from a store, the moment the sales clerk completes the sale, the store drops its accountability and responsibility for whatever use you make of it. Similarly, when a stock clerk issues an AF item to you, accountability is dropped insofar as the issuing authority is concerned. However, you do not become the owner of the item; instead, the Air Force keeps ownership, and you assume responsibility for the care and protection of the item.

*Supervisory responsibility.* Supervisory responsibility applies to any person who exercises supervision over property received, in use, in transit, in storage, or undergoing modification or repair. Supervisors are responsible for selecting qualified personnel to perform the duties under their control and for properly directing or training them. They instruct their people in supply procedures in order to make sure of compliance with Air Force regulations governing property. Supervisors are also responsible for indoctrinating their personnel in the principles of supply discipline.

*Custodial responsibility.* Any individual who has acquired possession of Government property has custodial responsibility for it. Individuals are personally responsible for such property if it is issued for their official or personal use, whether or not they have signed a receipt for it. They are also personally responsible for any property under their direct control for storage, use, custody, or safeguarding.

"Finders, keepers" may apply in some circumstances but not to Government property. If you find Government property that may be lost, stolen, or abandoned you must assume custodial responsibility for it, and you must protect or care for it until it can be returned to the proper authorities. Personnel may be relieved of responsibility for a particular piece of property in a number of ways, depending upon the circumstances. For example, property may be turned back to base supply as being excess to the unit's needs. Other items may be transferred from the responsibility of one person or organization to that of another. Still other items may be damaged or lost through carelessness of the one that has custody, in which case the person may be held liable and may have to pay for them by deductions from their pay.

**Pecuniary Liability.** The word "pecuniary" means money. Personnel having property responsibility also have pecuniary liability to make good property loss, destruction, or damage due to their maladministration or negligence. Pecuniary liability may be shared by persons having command, supervisory, or custodial responsibility. If a person pays for an item of Government property, the property remains the possession of the Government. This

| BASE CIVIL ENGINEER WEEKLY WORK SCHEDULE ( PART I ) | WEEK ENDING | COST CENTER | APPROVED |
|---|---|---|---|
| | | | |

| LINE NO. | DESCRIPTION A | LABOR UTIL. CODE (LUC) B | MAN/ HRS. C | MANHOUR ALLOCATIONS MON SCHED | MON ACT | TUES SCHED | TUES ACT | WED SCHED | WED ACT | THU SCHED | THU ACT | FRI SCHED | FRI ACT | SAT SCHED | SAT ACT | SUN SCHED | SUN ACT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ASSIGNED | | | | | | | | | | | | | | | | |
| 2 | BORROWED | | | | | | | | | | | | | | | | |
| 3 | OVERTIME | 38 | | | | | | | | | | | | | | | |
| 4 | TOTAL AVAILABLE (total of items 1,2,and 3) | | | | | | | | | | | | | | | | |
| 5 | SUPERVISION | 31 | | | | | | | | | | | | | | | |
| 6 | TRAINING | 32 | | | | | | | | | | | | | | | |
| 7 | LEAVE | 33 | | | | | | | | | | | | | | | |
| 8 | ALL OTHER | 34 | | | | | | | | | | | | | | | |
| 9 | LOANED LABOR | 39 | | | | | | | | | | | | | | | |
| 10 | TOTAL INDIRECT (total of items 5 through 9) | | | | | | | | | | | | | | | | |
| 11 | AVAILABLE FOR WORK (Items 4 minus item 10) | | | | | | | | | | | | | | | | |
| PART II (RESERVED MAN-HOURS) | | | | | | | | | | | | | | | | | |
| 12 | EMERGENCY JOB ORDERS | 12 | | | | | | | | | | | | | | | |
| 13 | DIRECT SCHEDULED WORK | 16 | | | | | | | | | | | | | | | |

THE ITEMS BELOW COMPETE FOR AVAILABLE MAN/HRS. (SCHEDULED WORK)

| WORK ORDER JOB ORDER NUMBER | DESCRIPTION A | (LUC) B | MAN/HRS REQ. C | MON SCHED | MON ACT | TUES SCHED | TUES ACT | WED SCHED | WED ACT | THU SCHED | THU ACT | FRI SCHED | FRI ACT | SAT SCHED | SAT ACT | SUN SCHED | SUN ACT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RECURRING MAINTENANCE | 11 | | | | | | | | | | | | | | | |
| | OPERATIONS AND SERVICES | 19 | | | | | | | | | | | | | | | |

AF FORM MAY 78 561 PREVIOUS EDITION IS OBSOLETE. *SCHEDULER'S COPY*

Figure 2-6. AF Form 561.

60

keeps the supply system from becoming a source of supply for individual personnel.

*Cash collection voucher*. When pecuniary liability is admitted, the least troublesome way to settle a monetary obligation is to pay in cash. DD Form 1131, Cash Collection Voucher, shown in figure 2-7, is used for this purpose. Note that the voucher shown is for the month of July. During this period, two airmen admitted pecuniary liability for lost or damaged articles and agreed to reimburse the Government in cash. Note also that the document shows the complete description of the items involved and the purpose for which collection was made.

*Statements of charges*. If airmen or civilian employees admit liability but do not have the money to pay cash for property damaged or lost, DD Form 362, Statement of Charges for Government Property Lost, Damaged or Destroyed, is used, as shown in figure 2-8. On this figure, note the four names listed numerically in lower left portion. They correspond to the numbered entries to four columns under "quantities" near the top center of the figure, showing quantities charged against each individual. Note that the Total Charge column shows a grand total of $28.39, which represents the amount owed after deducting the depreciation computed at 25 percent of the total value of $37.85. If an officer admits pecuniary liability and can't pay in cash, DD Form 114, Military Pay Order, is used, which authorizes deduction from such an officer's pay. Note that when the Cash Collection Voucher or the Statement of Charges is used, the amounts involved must be less than $500. If $500 or more is involved, then the Report of Survey is used.

*Report of Survey*. Whenever an individual will not admit pecuniary liability or when the amount involved is $500 or more, a DD Form 200, Report of Survey (as shown in fig. 2-9) must be used.

Two officers are directly concerned in preparing a Report of Survey: the appointing authority and the investigating officer. The appointing authority is the commander or another officer who has jurisdiction over the individual with custodial responsibility for the property in question. The appointing authority appoints a survey officer (the investigating officer) whose job it is to make a detailed and impartial investigation (survey) of the circumstances connected with the loss, damage, or destruction of the property described on the Report of Survey.

A survey officer is not necessarily appointed in every instance. When circumstances do not appear to warrant such a step, the appointing authority may make his own recommendations and send the Report of Survey to the base commander for review and approval.

As a result of the findings, the person who is responsible for the custody of the property in question may or may not be required to pay for it. In the case shown in figure 2-9, SSgt Gibson will be relieved of the responsibility of the flying jacket and will not have to repay the Air Force if the Report of Survey is approved.

If the authorities decide from the evidence that the responsible individual was negligent in caring for the property involved, then he has to reimburse the Government by paying in cash (the Cash Collection Voucher) or authorizing a pay deduction (Statement of Charges).

**Exercises (032):**

1. Match the type of responsibility, liability, or title of form required for circumstances or concepts in column A with the property accountability and responsibility in column B.

| Column A | Column B |
|---|---|
| ____ (1) Requirement make good the loss of property. | a. Supervisory responsibility. |
| ____ (2) Loss of property in excess of $500. | b. Custodial responsibility. |
| ____ (3) DD Form 1131. | c. Pecuniary liability. |
| ____ (4) Admit liability and pay for property lost. | d. Cash Collection Voucher. |
| ____ (5) Indoctrination in supply procedures. | |
| ____ (6) Detailed investigation concerning loss of property. | |
| ____ (7) Admit liability but do not have the money to pay for the loss. | |
| ____ (8) Can't pay cash or there is less than $500 involved in the loss. | |
| ____ (9) Least troublesome way to settle for loss. | |
| ____ (10) Take care of property you find. | |
| ____ (11) Means "money." | |
| ____ (12) DD Form 362. | |

**033. Specify the criteria for equipment authorization and identify aspects of the most common Authorization Documentation.**

Before you can start to work on a job, you must have the proper tools and equipment for doing the job. The equipment authorized for your shop is based on two things—the unit mission and the number of people. These two are interrelated. For example, if performance of the mission requires authorization for certain vehicles or similar major items, then operator personnel must be authorized; as personnel are authorized, quantities of other types of equipment based on number of personnel are affected.

**Equipment Authorization.** Bases obtain supplies and equipment and issue them to units according to an authorization system. Although there are a variety of authorization documents, the most common one is the table of allowance (TA). Such tables are published to prescribe exact items and quantities that each base or unit may draw (procure) to perform its mission.

A TA lists equipment on the basis of the needs of average Air Force units, since the exact composition and mission, number of aircraft belonging to the unit, its geographic location, and many other factors vary from one unit to another. Naturally these factors have a bearing on the types and amounts of items that a unit requires.

The master equipment management index (MEMI) is used in connection with the TAs. This document is

| CASH COLLECTION VOU''ER | DISBURSING OFFICE COLLECTION VOUCHER NUMBER<br><br>RECEIVING OFFICE COLLECTION VOUCHER NUMBER<br>355-00246 | |
|---|---|---|
| RECEIVING OFFICE — ACTIVITY (Name and location)<br>Department of the Air For :, BEMO, Winter AFB, Utah | | |
| RECEIVED AND FORWARDED BY (Printed name, title and signature)<br>HENRY J. SMITH, LtCol, USAF<br>Chief, BEMO | | DATE<br>3 July 19___ |
| DISBURSING OFFICE — ACTIVITY (Name and location)<br>Accounting and Finance Office, Winter AFB, Utah | | |
| DISBURSING OFFICER (Printed name, title and signature)<br>M. R. HERRIN, Major USAF<br>Accounting and Finance SN B4436 | DISBURSING STATION SYMBOL NUMBER<br>G75-0827695 | DATE RECEIVED SUBJECT TO COLLECTION |

**PERIOD:** From To

| DATE RECEIVED | NAME OF REMITTER DESCRIPTION OF REMITTANCE | DETAILED DESCRIPTION OF PURPOSE FOR WHICH COLLECTIONS WERE RECEIVED | AMOUNT | ACCOUNTING CLASSIFICATION |
|---|---|---|---|---|
| | Jack C. Hanson<br>SSgt, USAF,<br>FR 421-03-1725<br>(Cash) | 1 Each 7110-266-7444<br>CASE, Mail Distribution, portable, folding type, aluminum frame, wood top and bottom, cotton duck, intermediate partitions.<br>UNIT PRICE $12.50<br>(Lost through neglect) | $ 12.50 | |
| | Ivan B. Cooper<br>SSgt, USAF,<br>FR 321-16-7132<br>(Check) | 1 Each 7110-132-6648<br>BLACKBOARD, stand type, reversible, double face, black slate, 3' x 3' with eraser trough<br>UNIT PRICE $10.50<br>(Damaged beyond econmi-cal repair through carelessness) | 10.50 | |
| | | USED IN LIEU OF REPORT OF SURVEY<br>(Support Equipment)<br><br>APPROVED: HENRY G. SAMPSON, Major, USAF<br>Commander<br>370th Bomb Squadron (M)<br><br>Depreciation is not authorized. | | |
| | | **TOTAL** | $ 23.00 | |

**DD** FORM APR 67 **1131**

Form approved by Comptroller General, U.S. 24 January 1956

Figure 2–7. DD Form 1131.

**STATEMENT OF CHARGES FOR GOVERNMENT PROPERTY LOST, DAMAGED OR DESTROYED**

MILITARY PAY ORDER NUMBER

DATE: 15 APR 80

CLASS OF PROPERTY: AIR FORCE (SE)

ORGANIZATION: 3750 AIR BASE GP

FOR MONTH OF: MARCH

STOCK RECORD ACCOUNT OR OTHER PROPERTY RECORD OF ACCOUNTABLE OFFICER: EAID No. 370391750000

STATION: SHEPPARD AIR FORCE BASE, TX.

| STOCK NO. | ARTICLES | QTY 1 | QTY 2 | QTY 3 | QTY 4 | QTY 5 | QTY 6 | QTY 7 | TOTAL ARTICLES | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7210-160-0375 | COMFORTER, BED | | 1 | | 1 | | | | 2 | $10.40 | $20.80 |
| 7210-221-0352 | BLANKET | 1 | | | | | | | 1 | $8.05 | $8.05 |
| 7210-527-6089 | COVER MATTRESS | 1 | | 1 | 1 | | | | 3 | $3.00 | $9.00 |
| | * DEPRECIATION COMPUTED AT 25% | | | | | | | | | | $-9.46 |
| | | | | | | | | | | GRAND TOTAL | $28.39 |

CERTIFICATE OF RESPONSIBLE INDIVIDUALS

I certify that my signature hereon consititues:

a. An authorization to recover the amount of indebtness by payroll deduction.

b. An affirmation that the articles are not now in my possession.

c. An agreement to turn in to the appropriate supply officer all articles later recovered, it being understood that the United States Government retains title to the articles listed hereon.

| COL NO. | NAME, GRADE AND SOCIAL SECURITY NUMBER | CAUSE FOR CHARGE | TOTAL CHARGE | SIGNATURE | AMOUNT ACCEPTED |
|---|---|---|---|---|---|
| 1 | NAME FRANCIS L. FISHER<br>GRADE MSGT<br>SSN FR 697-40-2818 | LOST THRU NEGLECT | $8.29 | Francis L. Fisher | |
| 2 | NAME JAMES K. DOE<br>GRADE SSGT<br>SSN FR 378-56-8045 | LOST THRU NEGLECT | 7.80 | James K. Doe | |
| 3 | NAME FRED B. SMITH<br>GRADE A1C<br>SSN FR 376-85-0481 | LOST THRU NEGLECT | 2.25 | Fred. B. Smith | |
| 4 | NAME CECIL JACKSON<br>GRADE A1C<br>SSN FR 180-29-1684 | LOST THRU NEGLECT | 10.05 | Cecil Jackson | |
| 5 | NAME<br>GRADE<br>SSN | | | | |
| 6 | NAME<br>GRADE<br>SSN | | | | |
| 7 | NAME<br>GRADE<br>SSN | | | | |
| | | GRAND TOTAL | | | |

ORGANIZATION COMMANDER

Th... tements hereon are complete and correct, all damaged pr... as been disposed of in accordance with current direc-t... the charges have been computed in accordance with the ... of AR 735-11 (AFM 67-1 for USAF).

...O

SIGNATURE: David O. Watson
LT. COL. USAF
COMMANDER

DISBURSING OFFICER OR PAYROLL CERTIFYING OFFICER

The charge set opposite the name of each person listed hereon has been entered on the appropriate pay record or payroll, or DD Form 139 has been prepared and forwarded for collection.

DATE: 15 APR 80

SIGNATURE: Ray Hawkins, Maj USAF

PROPERTY VOUCHER NUMBER

...ORM ...AR 74 **362**

Figure 2–8. DD Form 362.

| REPORT OF SURVEY | | | 1. DATE 4 Nov 82 | | 2. SURVEY NUMBER | |
|---|---|---|---|---|---|---|
| 3. CLASS OF PROPERTY Air Force-Individual | 4. STOCK RECORD ACCOUNT OR OTHER PROPERTY RECORD AND STATION 370th Bomb Wg (M), Winter AFB, Utah | | | | | |
| 5. ACCOUNTABLE OR RESPONSIBLE OFFICER *(Name, grade, SSN and designation)* LARRY J. LEBLANS, LtCol, USAF, 123456A Chief, BEMO Winter AFB, Utah | | | | | | |
| 6. NATIONAL STOCK NUMBER | 7. DESCRIPTION | | 8. QUANTITY | 9. UNIT PRICE | 10. TOTAL COST | 11. DISPOSITION |
| 8415-268-7763 | Jacket, flying, man's Type B-15D, Size 36 | | 1 ea | | $15.00 | |
| | GRAND TOTAL | | | | $15.00 | |
| | RECOMMENDED PECUNIARY CHARGE → | | 12. FOR LOSS | | 13. FOR DAMAGE | |

14. DATE AND CIRCUMSTANCES

On 18 October 1982, item was issued on AF Form 538, Personal Clothing and Equipment Record, to SSgt David V. Gibson, FR 017-03-1723. On 22 October 1982, SSgt Gibson reported the loss of subject item to me and to the Director of Security and Law Enforcement. He stated that the item was removed by a person or persons unknown from the coat rack in dining hall No. 2 during the dinner meal on 22 October 1982.

See Exhibits "A" and "B" attached.

15. **AFFIDAVIT**

I do solemnly swear *(or affirm)* that *(to the best of my knowledge and belief)* the articles of public property shown above and/or on attached sheets were lost, destroyed, damaged, or worn out in the manner stated, while in the public service.

SIGNATURE

NAME, GRADE, SSN AND ORGANIZATION
LtCol, USAF, 123456A
Chief, BEMO
370th M&S Group

SUBSCRIBED AND SWORN TO *(or affirmed)*

BEFORE ME AT Winter AFB, Utah

THIS 6th DAY OF November 1982

SIGNATURE

NAME, GRADE, SSN AND ORGANIZATION OR TITLE; IF NOTARY PUBLIC, AFFIX SEAL
DAS, 370th Bomb Wg (M)
Authorized to administer oaths & act as a notary public under 10 USC 936 and AFR 20-16

16. **CERTIFICATE**

I certify that the loss, destruction, damage, or unserviceability of the articles of public property shown above, and/or on attached sheets, was caused in the manner stated and without fault or neglect on my part, and that each article listed with a view to elimination by destruction has been examined by me personally, has never been previously condemned, and is, in my opinion, worthless for further public use.

SIGNATURE *(Accountable or Responsible Officer)*

NAME, GRADE, SSN AND ORGANIZATION

17. HEADQUARTERS

STATION | DATE

TO

YOU ARE APPOINTED SURVEYING OFFICER

BY ORDER OF

SIGNATURE OF ADJUTANT/EXECUTIVE OFFICER & DATE

18. THIS SPACE RESERVED FOR ACTION BY AUTHORITY OF:

19. PROPERTY VOUCHER NUMBER

DD FORM 1 DEC 73 200 PREVIOUS EDITION WILL BE USED.

Figure 2-9. DD Form 200.

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published as TA–001, which provides a consolidated listing of equipment items in accordance with the latest stocklists. The items are cross-referenced to table of allowance numbers for the particular equipment items prescribed. AFR 0–10 also lists all TAs and a brief description of what is in each.

The procedure followed in using TAs with the MEMI is as follows: Suppose you wish to find out what type of equipment your shop is authorized. First, look up the item by name (for example, trucks) in the latest USAF Stocklist. This will give you the class number in the descriptive portion, which will enable you to choose the truck that is best for your use. At this point, you will find the complete stocklist number and the correct nomenclature (description) for the truck you want.

Take the stocklist number and look it up in the MEMI, that lists the stock numbers in numerical order. This will refer you to the correct TA numbers. Check the TA to which you have been referred by the MEMI and it will tell you how many trucks your unit is authorized. The TA takes into consideration not only the kind of unit to be equipped but also the total manpower employed.

When your shop was set up, a supply/equipment authorization document was drawn up. This document will list the TAs you will go by to get supplies and assign your shop a supply code. Some of the TAs you will use in the interior electric shop are as follows:

*a*. TA–001, Master Equipment Management Index (MEMI).

*b*. TA–006, Organizational and Administrative Equipment.

*c*. TA–008, Civil Engineer Equipment.

*d*. TA–010, Vehicles.

*e*. TA–016, Special Purpose Clothing and Personal Equipment.

*f*. TA–468, Civil Engineering Electrical, Instruments and Control Shop, Line Construction, Maintenance, Appliance Shop, Family Housing Repair Equipment, and Energy Monitoring Control System.

Refer to the preface of each TA to find out what column your shop will be listed in. Just because an item is listed in the TA for your shop does not mean you can get it.

You will be required to fill out a 601b, Custodian Request/ Receipt, and get it approved by your commander. Details on how to use the 601b will be covered in the next objective. It is your responsibility to order supplies on the basis of NEED and not NICE TO HAVE.

**Exercises (033):**

1. What is the criteria for equipment authorization?

2. What is the equipment authorization document most commonly used in the Air Force?

3. What is the TA based on?

4. In what TA wold you find equipment authorization?

**034. State the purpose of AF Form 601b and prescribe your responsibilities as equipment custodian.**

You will have the responsibility for the supplies and equipment used in your shop. This will range from the pencils and paper on your office desk to the DIN truck and all the tools and equipment stored in it. In order for you to effectively manage the resources you use, you will need to know the background and procedures used to control and document the supplies you use.

**Equipment Requisitioning.** Equipment authorization is based on a record of nonexpendable equipment that is accounted for by the chief of supply. You may be in charge of your shop's equipment account. If you are, you will be notified by letter and required to go to the equipment custodian school. This school, along with information found in the 67 series of Air Force standard publications, will help you understand the supply system used in the Air Force. The people in the BCE material control section will also be there to help you.

If you are the supply custodian, you will be directly responsible for the equipment issued to your account. You will inventory your account periodically to make sure that all items are on hand and serviceable. Fill out and send AF Form 601b Custodian Request/Receipt to supply for any changes you make to your account. Be sure to record your request on AF Form 126, Custodian Request Log. You will also need to insure that items that need inspection, repair, calibration, adjustment, or other work are taken care of through the appropriate agencies.

In the event of change of custodian, the old and new custodians go to supply to transfer the custody receipt account. The new custodian will then go to the equipment custodian school before taking over the account. Both custodians (old and new) make sure that all discrepancies are cleared up before the account is transferred.

Use AF Form 601b to ask for allowance and authorization changes, ordering new equipment, turn-ins, or updating equipment. Figure 2-10 shows an example of a filled out 601b. Information on the procedures to fill out 601bs and how to maintain your files are found in Chapter 8 of AFR 67–23, *Standard Base Supply Customer's Guide*.

**Individual Clothing and Equipment.** Individual clothing and equipment are obtained from the Individual Equipment Unit (IEU). TA–016 is the main source. The basis of issue is listed in TA–016 for a specific AFSC or job. In most cases, the basis is variable depending on local factors such as geographical location and types of job specialties or systems supported. Individual equipment items and toolkits are controlled through the equipment management office (EMO) tool issue center.

1. NAME OF CUSTODIAN-PHONE NUMBER-ORGANIZATION/CUSTODIAN CODE: John B. Smith ex 3859 2063N

2. CUSTODIAN REQUEST NO.: IN 4081-1

3. BEMO/EMO CONTROL NO.:

4. AF FORM 601A CONTROL NO.:

| 5. STOCK NO. AND/OR PART NO. | 6. IN-USE DETAIL DOC. NO. | 7. ALLOWANCE IDENT. | 8. PRESENT QNTY AUTH. | 9. QNTY. IN USE INCLUDE SUBS | 10. QNTY. REQ'D NEW AUTH. | 11. QNTY. REQUESTED | 12. UNIT OF ISSUE | 13. UNIT COST | 14. UND | 15. FAD | 16. USE CODE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6625-01-083-5979 | | 6292B00 | 1 | 0 | | 1 | ea | $400.00 | C | 4 | |

ACTION REQUESTED

23. AUTHORIZATION
- [ ] INCREASE
- [x] ADD
- [ ] REDUCE
- [ ] DELETE

24. ISSUE/DUE OUT
- [ ] ADVICE CODE
- [x] INITIAL ISSUE
- [ ] CANCEL D/O
- [ ] REPLACEMENT ISSUE

25. TURN-IN [ ]

CONDITION
- [ ] SERVICEABLE
- [ ] REPARABLE
- [ ] CONDEMNED
- [ ] UNKNOWN

STATUS
- [ ] COMPLETE
- [ ] INCOMPLETE[1]

CALIBRATION REQUIRED YES [ ] NO [ ]

CLEAN/PAINT REQUIRED YES [ ] NO [ ]

DISASSEMBLY REQUIRED YES [ ] NO [ ]

17. BUDGET CODE:

18. ERRC:

19. ITEM DESCRIPTION: Vibroground w/Acc Case

20. CUSTODIAN SIGNATURE: John B. Smith

21. TRANSACTION SERIAL NO.:

22. JUSTIFICATION OR EXPLANATION OF REQUEST

One per organization authorized to perform routine maintenance in accordance with AFR XX-XX and TO XXX-XXX-X. This item is necessary for calibration of Cathodic Protection Systems in service.

26. I certify that I have evaluated this request and the action requested herein is required.

SIGNATURE OF ORGN. COMDR.: Robert J. Caldwell

27. ACTION TAKEN BY EMO/BEMO
- [ ] APPROVED AS REQUESTED
- [ ] APPROVED AS INDICATED
- [ ] DISAPPROVED (See block 22)
- [ ] ADDITIONAL INFORMATION REQUIRED (See block 22)

SIGNATURE/BEMO/EMO/EAA

RECEIPT OF PROPERTY ACKNOWLEDGE (Signature-Receiving Custodian)

DATE AVAILABLE FOR PICK-UP

28. BEMO/EMO COMMENTS AND/OR OTHER REVIEWING ACTIVITY COMMENTS

[1] Enter Missing Components in Block 22

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

| 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

AF FORM APR 70 601b — CUSTODIAN REQUEST/RECEIPT

Figure 2-10. AF Form 601b.

**Exercises (035):**

1. Who accounts for nonexpendable equipment as recorded in base supply?

2. Why do you inventory your account periodically?

3. What is AF Form 126, Custodian Request Log used for?

4. What must be done before a new custodian takes over an equipment account?

5. What is AF Form 601b used for?

6. What TA is the main source for individual clothing and equipment allowance?

**035. State the procedures used to order materials for BCE job orders and service calls and name the section you must go through for approval.**

**Material Control Support.** The material control section processes request for materials, monitors the status of requirements, and gives information on the availability of material. This section controls all material needs in the BCE organization except janitorial and administrative supplies.

This unit follows procedures set up by AFM 67–1, *USAF Supply Manual*, Volume II, Part 2, Chapter 19. A BCE central tool control center is used to provide all shop tools, tool kits, and so forth. Material control manages a centralized bench stock at some bases.

Materials are requisitioned by the planning section of BCE, the service call desk for job orders, and by you or the people in your shop. You will complete an AF Form 1445, Materials and Equipment List, as shown in figure 2-11. The form is routed through the service call desk and controller. They will enter the job order on it and send it to material control. When the materials are received, the job can be finished.

AF Form 1445 is used for all material requests except for Base Service items, individual equipment and tool issue items, EAID items, and bench stock replenishment. When you pick up materials from the BCE holding area, take the AF Form 1445 with you and compare the materials you are picking up against the items on the form. Check the nomenclature to be sure that the item you are to pick up is the same as the one described on the form. Also, check the unit of issue to make sure that they agree with what you are picking up. If these items do not agree, don't sign for any of the items. Report any discrepancies to material control.

**Exercises (035):**

1. What BCE section controls the materials you will receive in your shop?

2. Where must you route an AF Form 1445 before it goes to Material Con. ɔl?

3. Why should you take your copy of AF Form 1445 with you when picking up materials?

**036. Specify the procedures that pe: .ın to the establishment of bench stock.**

**Bench Stocks.** A bench stock of common nonrecoverable hardware items, such as nuts, bolts, and screws, must be established in each shop. Bench stock is made up of low cost, expendable items which, due to regular use, are put at the point of use before actual use or need. The main advantage to this system is that the items are available to the user at once. Failure to maintain adequate bench stock items and levels can disrupt your work schedule just as much as nonavailability of workers. Although not repairable themselves, bench stock items are needed to repair other items. The on-hand quantity of bench stock items does not normally exceed a 30-day issue requirement, except where the unit of issue is package, kit, etc. When it is considered feasible, the package or kit is issued as bench stock.

*Establishing bench stock.* When a bench stock is authorized, a list of the required items and quantities is submitted to Material Control. Material Control and the base supply bench stock unit then review the list to determine if demands justify the items and quantities requested.

Each bench stock item is assigned a 4-digit serial number by the bench stock support unit. This number serves as the bench stock and bin location identifier and is part of the 14-digit document number for all supply transactions. Each item retains this item serial number until it is deleted from bench stock, even though the stock number may change. The document number contains the following data: the first digit, bench stock code (always B); the next three digits, the organizational code; the next two digits, the shop code; the next four digits, the date of the last demand; and the last four digits, the item serial number.

AF FORM 1445, MAR 80, PREVIOUS EDITION WILL BE USED.

TRANSACTION IDENTIFICATION CODE (1) 1 S U | DELIVERY DESTINATION (2)

## MATERIALS AND EQUIPMENT LIST

| I E X (3) | STOCK NUMBER (4) | NOMENCLATURE | UNIT OF ISSUE (5) | QUANTITY (6) | UNIT COST | TOTAL COST | TRANS. SERIAL NUMBER (11) | DEMAND CODE (12) | IN STOCK YES | IN STOCK NO | DATE EXPECTED | REC. BY BCE | EXCESS MATERIALS QUAN. | EXCESS MATERIALS DISPOS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PLU 150MV | MERCURY VAPOR LAMP | EA | ØØØ12 | 26.00 | $312.00 | | | | | | | | |

ACTIVITY CODE (7) | ORGANIZATION CODE (8) 900 | SHOP CODE (9) IT | DATE MATERIAL REQ. (10) 836Ø | WORK ORDER NO. (13) ØØØ35Ø | TRANSACTION EXCEPTION CODE (14) | MATERIAL CONDITION (15) | FORCE ACTIVITY DESIG. (16) | SYSTEM DESIGNATOR (17) | PROJ. CODE (18)

DELIVERY PRIORITY (19) | REQUIRED DELIVERY DATE (20) | URGENCY JUSTIFICATION CODE (21) | FACILITY NO. (22) | INST. CODE (23) ZWVP | JOB ORD. NO. (24) A 1Ø23 | PLANNER DIX | PAGE 1 OF 1 PAGES | HOLDING AREA BIN LOCATION

SHOP TITLE 471 | RECEIVED BY | MONTH | FOLLOW-UP DATA FOR BACK ORDERED MATERIAL 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 | WORK ORDER NO.

Figure 2-11. AF Form 1445.

**Exercises (036):**

Complete the following statements establishing bench stock by filling in the blanks with the appropriate word or words. response. May require more than one word.

1. Nonrecoverable hardware items that are stored in the local work area so that they are available for immediate use are referred to as __________ __________.
2. The bench stock level does not normally exceed a __________ __________ requirement.
3. When a bench stock is established, a list of items and quantities is submitted to __________ __________.
4. The first digit of the 14-digit document number pertains to the __________ __________.

## 037. Associate duties related to bench stock with the units responsible for doing them.

**Bench Stock Responsibilities.** If your bench stock is set up in your shop, there are several responsibilities that you may have. Some of your shop or section responsibilities are to:

*a.* Document issues from bench stock.

*b.* Prepare and take care of any shadow boards.

*c.* Provide adequate storage facilities, including bins for the bench stock.

*d.* Take care of and safeguard bench stock. Set up local controls to secure sensitive items.

*e.* Flag bench stock items with a red indicator if the bin has 50 percent or less of the authorized quantity.

The Bench Stock Support Unit is responsible for:

*a.* Conducting a weekly walk-through of each bench stock. Flagged items are checked and replenishment action must be taken if an item is out or is expected to be out of stock before the scheduled date of the next inventory.

*b.* Conducting monthly inventories of all bench stock and refilling all bins that are less than 50 percent of the authorized level.

*c.* Delivering and binning material for all on-base bench stock.

*d.* Labeling all bins.

*e.* Turning in all excess and deleted stocks.

*f.* Installing, updating, and maintaining a placard in a noticeable place in the bench stock area with the following headings:

(1) Organization and shop code.

(2) Date of last inventory.

(3) Date of next inventory.

(4) Date of last walk-through.

(5) Telephone number of the office to get in touch with to solve bench stock problems.

NOTE: If an item becomes out of stock between the weekly walk-throughs and no due-out or kill document is in the bin, then you may ask the Bench Stock Support Unit for replenishment at once. You should check with the chief of supply to find out how to fill out urgent bench stock needs.

**Exercises (037):**

1. Match the duties in columm A with the correct unit from column B.

| *Column A* | *Column B* |
|---|---|
| ____ (1) Flags bench stock items with a red indicator. | a. Your shop or the supported activity. |
| ____ (2) Document issues from bench stock. | b. The Bench Stock Support Unit. |
| ____ (3) Labels all bins. | |
| ____ (4) Safeguards bench stock. | |
| ____ (5) Delivers material for on-base bench stocks. | |
| ____ (6) Conducts a weekly walk-though of each bench stock. | |
| ____ (7) Prepares and takes care of any shadow boards. | |

## 038. Identify equipment and supply condition tags with the conditions they signal.

**Condition Tags.** These forms, which are actually colored cardboard tags, are attached to pieces of equipment and material to be turned in denoting the condition of each item. A yellow, DD Form 1574, Serviceable Tag—Materiel, as shown in figure 2-12, is attached to serviceable equipment. A green, DD Form 1577-2, Unserviceable (Reparable) Tag—Materiel, as shown in figure 2-13, is attached to equipment that is inoperative. A red, DD Form 1577, Unserviceable (Condemned) Tag—Material, as shown in figure 2-14, is attached to material that is not worthy of repair. If you have colored pencils available, you may want to color the tags in your CDC.

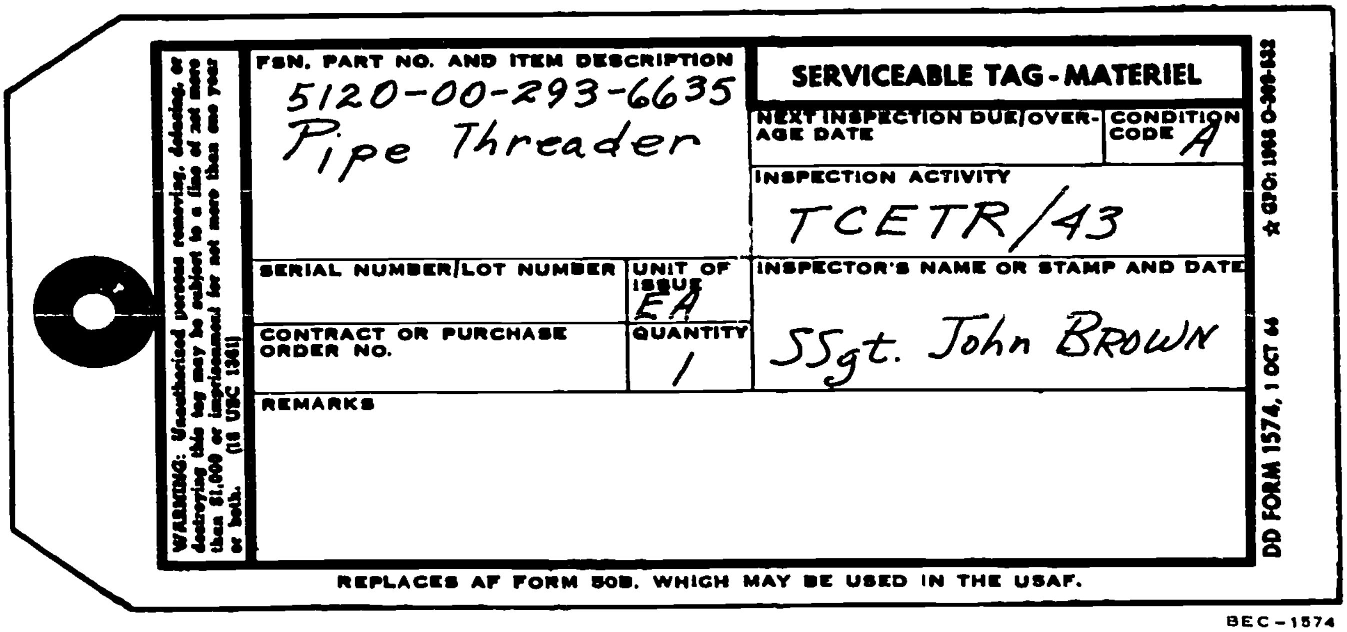
**Exercises (038):**

1. Which color condition tag would you find on a serviceable item?

2. A piece of equipment has a green tag on it. What is its condition?

## 039. State the purpose of AF Form 1801 and prescribe the procedures regarding their completion.

**Issue and Turn-In Slips.** There are a number of supply forms that pertain to the requisitioning of an item. One you may use from time to time is AF Form 1801, Request for Issue or Turn-In. It is used for expendable-type items that you may need for shop use and not on a work or job order.



WARNING: Unauthorized persons removing, defacing, or destroying this tag may be subject to a fine of not more than $1,000 or imprisonment for not more than one year or both. (18 USC 1361)

FSN. PART NO. AND ITEM DESCRIPTION
5120-00-293-6635
Pipe Threader

SERVICEABLE TAG - MATERIEL

NEXT INSPECTION DUE/OVERAGE DATE

CONDITION CODE A

INSPECTION ACTIVITY
TCETR/43

SERIAL NUMBER/LOT NUMBER

UNIT OF ISSUE EA

CONTRACT OR PURCHASE ORDER NO.

QUANTITY 1

INSPECTOR'S NAME OR STAMP AND DATE
SSgt. John BROWN

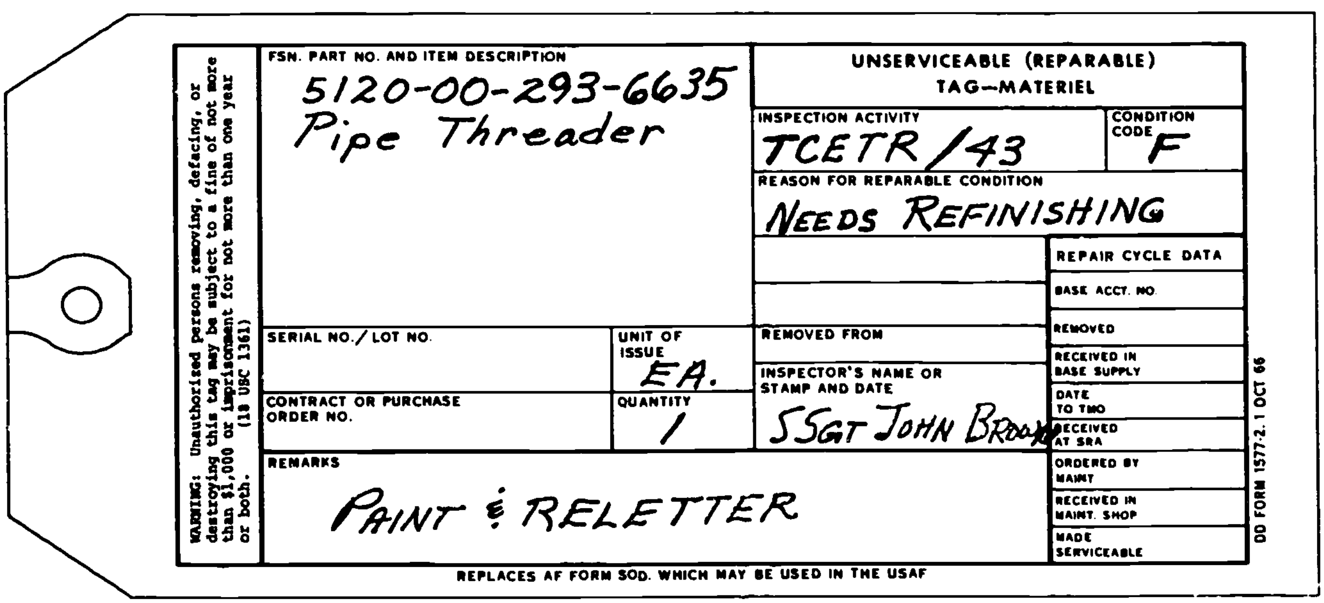
REMARKS

DD FORM 1574, 1 OCT 64 ☆ GPO: 1968 O-300-532

REPLACES AF FORM 50B, WHICH MAY BE USED IN THE USAF.

BEC-1574

Figure 2–12. DD Form 1574.



WARNING: Unauthorized persons removing, defacing, or destroying this tag may be subject to a fine of not more than $1,000 or imprisonment for not more than one year or both. (18 USC 1361)

FSN. PART NO. AND ITEM DESCRIPTION
5120-00-293-6635
Pipe Threader

UNSERVICEABLE (REPARABLE) TAG—MATERIEL

INSPECTION ACTIVITY
TCETR/43

CONDITION CODE F

REASON FOR REPARABLE CONDITION
NEEDS REFINISHING

REPAIR CYCLE DATA

BASE ACCT. NO.

REMOVED

RECEIVED IN BASE SUPPLY

DATE TO TMO

RECEIVED AT SRA

ORDERED BY MAINT

RECEIVED IN MAINT. SHOP

MADE SERVICEABLE

SERIAL NO./LOT NO.

UNIT OF ISSUE EA.

REMOVED FROM

CONTRACT OR PURCHASE ORDER NO.

QUANTITY 1

INSPECTOR'S NAME OR STAMP AND DATE
SSGT JOHN BROWN

REMARKS
PAINT & RELETTER

DD FORM 1577-2, 1 OCT 66

REPLACES AF FORM 50D, WHICH MAY BE USED IN THE USAF

Figure 2–13. DD Form 1577–2.

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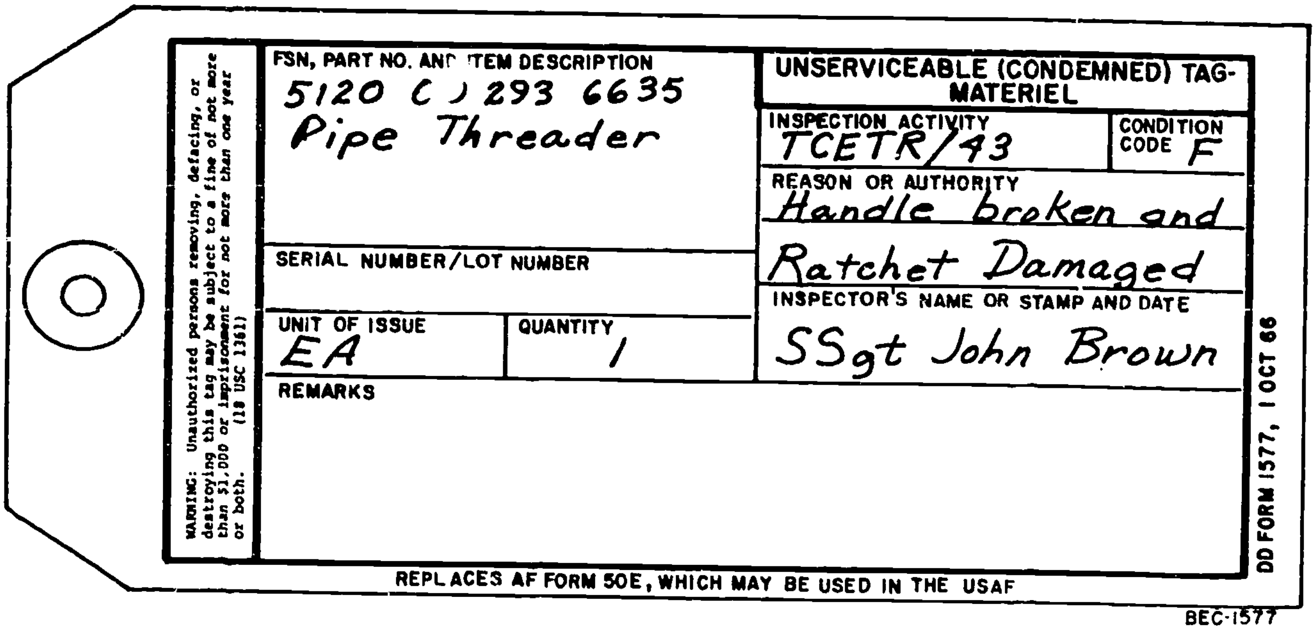
WARNING: Unauthorized persons removing, defacing, or destroying this tag may be subject to a fine of not more than $1,000 or imprisonment for not more than one year or both. (18 USC 1361)

FSN, PART NO. AND ITEM DESCRIPTION
5120 C J 293 6635
Pipe Threader

UNSERVICEABLE (CONDEMNED) TAG-MATERIEL

INSPECTION ACTIVITY: TCETR/43
CONDITION CODE: F

REASON OR AUTHORITY: Handle broken and Ratchet Damaged

SERIAL NUMBER/LOT NUMBER

INSPECTOR'S NAME OR STAMP AND DATE: SSgt John Brown

UNIT OF ISSUE: EA
QUANTITY: 1

REMARKS

DD FORM 1577, 1 OCT 66

REPLACES AF FORM 50E, WHICH MAY BE USED IN THE USAF

BEC-1577

Figure 2–14. DD Form 1577.

Figure 2-15 shows a completed AF Form 1801 requesting issue for six 5/8 auger bits and six leather work gloves. Note the issue block at the top of the page is filled in with an I. Now look at the bottom of the form and notice under issue that "I" means it is an initial issue. Always place a justification for the items after listing the last item. Local policies will determine the procedures for processing this form.

**Exercises (039):**

1. What is AF Form 1801 used for?
2. What would be the meaning of an R in the issue block at the top of the page?
3. What always follows the last item on the form?

**040. State the correct use of AF Form 1297, Temporary Issue Receipt.**

**Temporary Issue Receipt.** Figure 2-16 shows a completed AF Form 1297, Temporary Issue Receipt, for items issued on a temporary basis (normally, 24 hours). Once it is filled out, however, this receipt can remain in force until you return it to the one who is taking temporary custody. When you sign something out, be sure you get all the necessary information on the form. When equipment is turned back in, return the form to the individual.

**Exercises (040):**

1. For what purpose is the AF Form 1297 used?
2. Normally, how long is the AF Form 1297 used for items on a temporary basis?
3. What happens to the form when the equipment is turned in?

**041. Specify responsibilities and reference for reporting material deficiencies.**

**Materiel Deficiency Reporting.** As a general rule, you should not experience any great difficulty in using materials or equipment purchased by the Air Force. Such items must meet or exceed Federal specifications to be acceptable for use by the Air Force. Of course, you must use equipment or materials for the purpose for which they were intended. You must also use them according to instructions or directions which apply specifically to the item.

| REQUEST FOR ISSUE OR TURN-IN | I ISSUE / TURN-IN | SHEET NO. 1 | NO. OF SHEETS | 5. DOCUMENT NUMBER |
|---|---|---|---|---|
| 1. FROM: | 6. DATE MATERIAL REQUIRED | | | 7. FAD/UJC OR PRIORITY |
| 2. TO: | 8. DOCUMENT NUMBER | | | 9. POSTED DATE BY / DATE BY |
| 3. ACCOUNTING AND FUNDING DATA | | | | |
| 4. END ITEM IDENTIFICATION | A. NAME AND MANUFACTURER | B. MODEL | C. SERIAL NUMBER | D. PUBLICATION |

| ITEM NO. A | STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIAL AND OR SERVICES B | CODE C | UNIT OF ISSUE D | QUANTITY E | SUPPLY ACTION F | UNIT PRICE G | TOTAL COST H |
|---|---|---|---|---|---|---|---|
| 1. | XXXX-XX-XXX-XXXX, 5/8 auger bits | | ea | 6 | | .55 | $3.30 |
| 2. | XXXX-XX-XXX-XXXX, leather work gloves | | pr | 6 | | .45 | $2.70 |

///////////////////////////////////// Last Item ///////////////////////////////////////////

Justification: These items will be used to replace like items that have worn out due to fair wear and tear.

| FIA CODE | BUDGET CODE | SHEET TOTAL |
|---|---|---|
| | | GRAND TOTAL |

*ISSUE: I—Initial; R—Recurring; N—Non-Recurring TURN-IN: U—Unserviceable; S—Serviceable

| 10. ISSUE OR TURN-IN OF QUANTITIES IN "QUANTITY" COLUMN IS REQUESTED | DATE | BY | 11. RECEIVED QUANTITIES IN "SUPPLY ACTION" COLUMN | DATE | BY |
|---|---|---|---|---|---|

AF FORM OCT 71 1801 PREVIOUS EDITION WILL BE USED

Figure 2–15. AF Form 1801.

74

ISSUED TO NAME

TYPED OR PRINTED NAME, GRADE AND ORGANIZATION

ISSUERS Supervisor

TO: *(Responsible Officer)*

ORG. ACCT. NO.

DATE ITEM(S) TO BE RETURNED

| STOCK NO. | DESCRIPTION | UNIT | QUANTITY ISSUED | COST |
|---|---|---|---|---|
| XXX-XX-XXX | 3/4 inch CONDUIT BENDER | 1 | EA | $16.00 |
| | LAST ITEM | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

I ACKNOWLEDGE RECEIPT AND RESPONSIBILITY FOR ITEM(S) SHOWN IN "QUANTITY ISSUED" COLUMN, WHICH WILL BE RETURNED ON DATE SPECIFIED ABOVE.

| DATE | SIGNATURE | DUTY PHONE | ISSUED BY |
|---|---|---|---|
| | PERSON ISSUED TO | | YOUR NAME |

AF FORM SEP 70 1297 PREVIOUS EDITIONS WILL BE USED

**TEMPORARY ISSUE RECEIPT**

c48—18—83541-1 GPO

Figure 2-16. AF Form 1297.

If you do find equipment or materials that are substandard or defective, it is your responsibility to submit a materiel deficiency report. Refer to TO 00–35D–54, *USAF Materiel Deficiency Reporting System*, and AFR 66–30, *Product Improvement Program for Operational Equipment*, for guidelines to help you complete the report.

All personnel are responsible for submitting reports on substandard or defective materials and equipment. Such reports will improve the quality of materials and equipment used by USAF organizations.

**Exercises (041):**

1. Who is responsible for submitting a materiel deficiency report on an unsatisfactory item?

2. What references can be used for reporting materiel deficiencies?

# Supervision and Training

YOUR SPECIALTY description tells you that one of your responsibilities is to supervise electrician personnel. If you examine that description, you are sure to get at least one impression—that you need to know more than just how to install and maintain electrical systems. You need to know how to get along with people and how to keep them working effectively. You also need to know your job well and how to train the people who work for you to do a better job. That is what this chapter is all about, supervision and training.

## 3-1. Supervision

A prominent writer on management topics once wrote that: Supervision = job proficiency + leadership + management. But formulas are ordinarily summarizing devices and often oversimplify. In addition to the three traits, job proficiency, leadership, and management, a supervisor must be able to orient newly assigned personnel, establish priorities, schedule and make work assignments, and rate personnel. You can see from this list that a supervisor must be a person of "many hats." Supervisors must be able to change from one role to another at a moment's notice. Let's review some of the traits that a supervisor must possess and some of the jobs that they must perform.

**042. For given situations, indicate how you could fulfill your responsibility for the mission.**

**Responsibility for the Mission.** You are responsible for many things but your primary responsibility is the mission. Your duty to your unit and to your personnel are secondary only to the mission. There will be times when the people who work for you will want to be absent from duty for various reasons. They will feel hurt if you do not let them go, but you must disregard the needs and feelings of your personnel in order to meet the needs of the mission. At such times, the esteem your people hold for you will suffer unless they have been thoroughly briefed with responsibility for the mission. You should impress this fact upon them through talks, discussions, training, and personal example. In spite of such orientations, not all of your personnel will support you in these demands. There are always some who place personal desires before duty; however, they will eventually fall in line and follow the majority if you are firm and stand by the first objective of your job—THE MISSION IS PRIMARY.

Responsibility to your superiors is another objective that you must realize. If you fail to support your superiors, you jeopardize your own efforts. Whenever you criticize your superiors and their methods, you, in turn, invite criticism by your personnel. They will simply be following your example. To avoid this, you should carry out the directives of your supervisor as if they were your own. A good leader must be a good follower. Should you disagree with a directive, present your point of view to your supervisor. If the directive still stands, carry it out to the best of your ability without excuse, alibi, or any attempt to pass the buck. When you can do this, it is an indication of maturity. It is also an indication that you are ready for even greater responsibilities.

At times, you may be directed to do something contrary to directives from higher headquarters. When this happens, do not hesitate to bring it to the attention of your supervisor. If you are still directed to carry out the original order, do so without reluctance. In such a situation, your supervisor assumes full responsibility for this action. You must understand that he or she is nearer to the top and knows more than you do about the overall mission. Responsibility to the mission is your first consideration, regardless of how disagreeable the order may seem. This does not mean that you can be directed to falsify official documents. To do so would compromise your integrity—your truthfulness. To do so is not only unlawful but also degrading. John D. Ryan, General, USAF, when Chief of Staff said, "False reporting is a clear example of a failure of integrity. Any order to compromise integrity is not a lawful order."

**Shop Supervisor Responsibilities.** The duties and responsibilities of the interior electric shop supervisor are listed below. They do not include all responsibilities but should give you an idea of the areas that you must be concerned with if you are in charge of your shop.

*a.* Supervises and directs shop activities to maximize production. Assigns work to workers.

*b.* Ensures compliance with the work schedule.

*c.* Helps the superintendent set standards of maintenance to include developing the recurring maintenance program.

*c.* Makes sure workers have tools and shop equipment necessary to do their work.

*e.* Identifies requirements for operating supplies and special levels to material control.

*f.* Reviews the bench stock list and advises material control of problems.

*g.* Enforces supply discipline by seeing that only authorized material and spare parts are on hand.

*h.* Advises material control of excess, repairable, or condemned equipment, materials, spare parts, and tools.

*i.* Trains and provides operating instructions to users of equipment and appliances.

*j.* Helps the planners estimate work orders and job orders.

*k.* Makes sure required records and reports are accurate, legible, complete, and submitted on time.

*l.* Reviews workload to determine capability to do all scheduled work orders and job orders. Reviews should be done before the weekly scheduling meeting.

*m.* Exercises direct supervision over all assigned military and civilian personnel.

*n.* Maintains control of workers through the controller.

*o.* Makes final inspections to complete work.

*p.* Identifies training needs and provides the on-the-job training to assigned workers.

*q.* Makes sure workers provide an AF Form 1255, Quality Control Evaluation, to customers on arrival at the job site.

*r.* Makes periodic job site checks.

**Exercises (042):**

1. You are the supervisor. The rewiring of a facility for a new flight simulator must be completed within 2 weeks. You are slightly behind schedule. Airman Jones and Airman Smith want 3 days off to go camping.
   a. What is your first consideration?

   b. How would you handle Airman Jones and Airman Smith?

2. Sergeant Sims requests 10 days TDY to attend the JSIIDS (Joint Service Interior Intrusion Detection Systems) course. The interior shop is 2 people short and is behind on work orders. As the supervisor, what should you do?

3. Colonel Y. Knot calls and wants you to install a light switch on the back of his house that afternoon. This project is not on your production schedule. What should you do?

4. You have two pipe threaders in your shop that do not work. What are your responsibilities in this situation?

5. Two new airmen are assigned to your shop. What are your responsibilities to these people?

**043. Define job proficiency and state the importance of job proficiency as it relates to you job as a supervisor.**

**Job Proficiency.** In order to get out the work, you must be able to do your job well as a supervisor. If you were to make a list of the qualities of a good supervisor, you certainly would have to place job proficiency somewhere near the top of the list. You must know electrical work or you will not know if your workers are doing their jobs correctly or not. A big part of your job is training your workers on the job. How can you train others if you don't know how to do the job yourself? For example, one task in your career field is to install power panels. There is a correct way to do this task. There is also a dangerous way to do it. You must know the difference.

The best electrical worker does not always make the best supervisor because there are a lot of other qualities to being a good supervisor. However, to be respected by the people who work for you, you must be proficient in 542X0 skills.

**Exercises (043):**

1. What is job proficiency as it relates to this course?

2. What would be *two* likely results if you tried to supervise a group of 54250 personnel without knowing jobs of an electrician or being able to perform related tasks?

**044. Given situations requiring good leadership traits, state what traits you can use to handle the situation in a manner that will not reduce effective mission accomplishment.**

**Leadership.** You be able to lead people in order to get the work done. Most people can be led readily, but they do not like to be driven. The old "whip-cracking" boss went out with the horse and buggy.

Intelligent people who expect to be leaders must know the traits of good leaders so that they can practice them. A list of these traits, which is by no means complete, follows:

*a.* Leaders understand their personnel as individuals in spite of their sex, schooling, experience, age, race or religion.

*b.* Leaders can, when necessary, be firm with workers without losing their temper.

*c.* Leaders are not afraid of their positions, their own boss, the directives, or any tough jobs.

*d.* Leaders are easy to approach and also easy to get away from almost any time.

*e.* Leaders are people you can't fool, though they may have the good sense to look away at the right time.

*f.* Leaders know most of the answers, but will admit it when there is one they don't know. They will, however, know where to get the right answer.

*g.* Leaders can show their people how to do a job without showing off or showing up their employees.

*h*. Leaders are predictable.

*i*. Leaders are honest, but can see through trickery.

*j*. Leaders identify with their employees and will fight for them, provided they are in the right. Even when they are wrong, the leader will support them and encourage them to be right.

*k*. Leaders get a kick out of their work and are able to project their enthusiasm.

*l*. Leaders believe that their work is important.

*m*. Leaders will listen to something important but remember an "appointment" when they hear idle talk.

*n*. Leaders give the impression of trying to work themselves out of their jobs and work their people into them.

*o*. Leaders get around but do not gossip.

*p*. Leaders talk in terms of joint activity. They like to stress the word "we" and mean it.

The traits above refer, of course, to good leaders. The statements are written in positive terms. For a moment let's take a look at the other side of the coin and see some of the qualities of poor leaders. Poor leaders have a negative influence on those they supervise. "A shop is a reflection of the leader" is a statement that has much truth in it. A good leader reflects a good shop. A poor leader reflects a poor shop. If the leaders have poor morale, like a contagious virus, they will pass it on to their employees. This type of situation is created when supervisors are critical of their jobs, their supervisors, and those they direct. In such a case, dissatisfied supervisors can't create enthusiasm for work and for self improvement for members of their teams. Such failure results in low productivity, poor quality products, and personnel wanting to leave the shop.

Good leaders try to avoid conflicts between their people and higher level orders which they must pass on. A full explanation of an order will often prevent misunderstanding. In group or private conferences, leaders explain possible sources of friction before their people get excited. They do not let someone else inform them of something unpleasant concerning their jobs. They try to discover the basic reason for the order; and in passing the information on to those under their supervision, they explain the order.

**Exercises (044):**

1. In the following situations, state what leadership traits you should use to handle the situation in the most effective manner.
   a. One of your workers comes to you with a fluorescent dimming ballast component you are unfamiliar with.

   b. Sgt Hassle has a personal problem and needs someone to talk to.

   c. Sgt Anderson, a female, just arrived in your shop and tells you she is willing to accept any challenge.

   d. You overhear that Amn N. Trouble is having marital problems.

   e. You have two very capable NCO's in your shop who want to help with some of the responsibilities.

   f. A group of your workers are sitting in the break area discussing a job. As the conversation lengthens they begin to discuss the party they went to on Saturday night.

   g. Amn Tom Maker has been goofing off on the job.

   h. The O&M chief has directed that your shop is going to have to work on Saturdays for the next 3 weeks to catch up on backlogged work.

   i. In the past, you have let people off who have worked overtime on the weekend.

   j. The commander is on Sgt Morgan's back for cutting power to the Officer's Club during an emergency.

**045. List the questions and steps necessary to orientate new workers.**

**Orienting New Personnel.** When new workers are assigned to your shop, you should introduce them to the job and to the people with whom they will be working. This orientation is one of your most important responsibilities because this is when the new workers get their first impression of you and their new assignment. Their first impression is good or bad, depending upon how well you, the supervisor, conduct the orientation. The effects of bad orientation take a long time to correct, whereas good orientation satisfies the four basic needs of people—recognition, opportunity, security, and a feeling of belonging.

When new workers report for duty, remember that the orientation can be a distinctly motivating factor, because it can convince them that they have found a good job in an interesting and important place to work. Before you begin the actual orientation, introduce yourself, then guide the conversation along personal lines:

*a.* Get their names correctly, then remember and use their names as you proceed with the interview.

*b.* Find out their marital status and (if applicable) the number, age, and sex of their children.

*c.* Ask their age.

*d.* Ask about their education and experience and their special training and talents.

*e.* Check on their hobbies and interests.

*f.* Find out about their home background. (You may have mutual interests, or someone already working in the shop may be from the same locality.)

*g.* Find out where they are living. If they are living off base, offer to help them find a car pool or satisfactory transportation to work.

*h.* For each bit of information you get from them, try to give them a little in return, not only about yourself, but about the people with whom they will work.

With this information, you will know better how to orient new workers. Tell them to ask questions when they want further clarification; then give the official part of the orientation as follows:

*a.* The functions and organizational structure of the shop.

*b.* Where their positions fit into the organizational structure, and the importance of their positions.

*c.* The supervisory chain of command and the person to whom they are directly responsible.

*d.* Duties and responsibilities in their positions and the opportunities for advancement.

*e.* The concepts of career development and their relationship to the career program.

*f.* The new duties from the specialty description and specialty training standard that they will learn to perform in their assignment.

*g.* The standard of work required.

*h.* Specific shop procedures and policies (duty hours, special details, special meetings to attend, etc.).

Finally, introduce them to the other shop personnel. As you walk around, point out items of interest(emparticularly those that specifically relate to their former job. Don't burden them with a lot of small details that they won't understand. Leave the small details for them to learn when they actually start doing the tasks. Introduce them, not only as new workers but as people of interest. Say something about their qualifications or interests. Take special pains to introduce them to the people who come from the same part of the country or who may know the same people. Then introduce and turn them over to the people who will be responsible for their training.

During the following days and weeks, as they train on the job, be sure to give them any needed assistance, let them know how they are getting along, give them credit when due, and gain their confidence. You must learn all you can about their emotional stability and their ability to solve the problems that might otherwise have a bad effect on their work.

**Exercises (045):**

1. Sgt John A. Brown has just arrived on base from another base. He is assigned to your shop and you need to orientate him. In the space provided below, make up a brief list of questions intended to get information about him and his background.

2. In the space provided, outline the official information you must tell Sgt Brown.

### 046. State the procedures used to establish work priorities and work assignments.

**Work Priorities.** There are many questions that you must ask yourself in order to analyze the work distribution, establish priorities, and schedule work in your shop. Some of these questions are as follows:

*a.* Which jobs are the most urgently needed?

*b.* Which activities take the most time?

*c.* Are there any jobs that are misdirected?

*d.* Are the jobs assigned to the correct shop?

*e.* Is your shop required to do too many unrelated tasks?

*f.* Is the work distributed evenly?

*g.* Are supplies and equipment available to accomplish the job?

If you have the answers to these questions, you will be in a position to see the relationship of these different jobs and can come to a conclusion. This is not to be interpreted to mean that you don't already know what is going on in your shop. We are not talking about job classification or Air Force specialty when we discuss work priorities and work distribution. Rather, we are talking about specific, detailed, factual information that is assembled in one place in an orderly way to help you make improvements more easily. In order to be a good supervisor you should always seek new ways to improve your organization.

Obviously, the most time should be devoted to the most important work—those operations that contribute most directly to the mission of your organization. Operations should be the right number and type to accomplish this mission. Time totals for other operations normally should reflect the relative importance of that operation. By keeping on the alert when you study your work distribution, you will find that the effort expended is repaid many times over. Also, you will be surprised at how much you can learn about how the work in your unit is done.

Only operations and tasks that are essential to the organization's mission should be accomplished. Work that duplicates work done elsewhere may be misdirected effort. Misdirected effort often shows up in the form of excessive personal time or time not accounted for. Any work being performed that does not contribute to the mission is likely to be misdirected effort.

**Work Assignment.** After you determine that the work is the right type for your shop and you have it scheduled for completion by priority, the next thing that you must do is to assign the people to do the job. There are several questions that you can ask yourself to help you make these decisions.

Are skilled workers doing considerable routine work or other tasks that do not use their skills? The supervisor and skilled workers should do a minimum amount of routine or other unskilled work. This can be a problem with willing workers as they may take on work below their skills.

Do workers have tasks that are above their skills or for which they are not trained? Workers doing work far above their skills usually will do less work, do poorer quality work, and cause more accidents than workers with proper skills. Skilled work should be concentrated in some positions and unskilled work in others, where possible.

Are willing workers assigned tasks that are unrelated to their normal work? Few people can do all types of work equally well; the assignment of unrelated tasks to workers can result in poorer work, less enthusiasm, and more fatigue. The assignment of related tasks to a worker makes training to increase the worker's skills easier. Willing workers should not be assigned or allowed to assume too many tasks just because of their willingness. Tasks should be organized in related groups and then assigned to appropriate workers.

Are many workers doing a small or unimportant task that one person could do more efficiently? If several workers are filing, answering the phone, cleaning the shop, or doing some similar task, the task may be badly performed and skills may be wasted. Also, tasks may be given to so many workers that no one is responsible for them. One person working steadily usually can accomplish a task more effectively than many workers doing a small part of the same task.

What do you think happens if the work is not evenly or fairly distributed among your workers? Obviously, everyone won't be carrying a fair share of work. Worker morale will decrease, accidents may increase, and some workers may be idle or "goofing off." Overloading or underloading workers will get poor results. Aim for a balanced workload among workers.

**Exercises (046):**

1. What type of work takes first consideration when making out the schedule?

2. What is misdirected work?

3. Who in your shop should do the lesser skilled, routine-like work?

4. What problems could result by assigning your workers jobs far above their abilities?

5. What is an advantage to insuring workers are assigned to related tasks.

6. List two advantages to assigning one worker to perform a routine task.

7. What could result if the work is not evenly or fairly distributed?

**047. Given four rules for organization in management principles and four situations, associate the rules with the situations.**

**Management Principles.** Your job calls for you to supervise maintenance, inspection, and repair activities. In order for you to do a good job of supervising these activities, you must have some knowledge of management principles. Management may be defined as the process of organizing, coordinating, and using resources to accomplish work that has been planned. There are many other definitions and there are scores of books written on management. To express a complex subject in simple terms, you could say that management is using common sense to get the job done efficiently. This whole chapter, Supervision and Training, relates to management principles. This particular objective is limited to the portion of management called organization.

**Organization.** To practice good management principles, you must be able to organize. Organization is a process of putting things in order in some kind of working system. You organize your room when you get ready for an inspection. You organize your thoughts before you give a speech. You organize your job and the jobs of your workers, and you organize the steps and processes by the tasks that are accomplished. You may do these things consciously or unconsciously, but one way or another YOU DO ORGANIZE. There are four principles or rules which can help you to organize your unit effectively.

*Rule 1*. The first rule is that each person must have only one boss. He or she should take orders from that one boss and receive directives and directions from only that boss. Have you ever been in a position where the big boss gave you orders that were different from those that your supervisor gave you? It is very confusing to say the least. An armed force will lose its effectiveness when the chain of command is broken—so will a shop. The saying that "no man can serve two masters" is as true today as it was 2000 years ago. Every person must know who their boss is and must take orders from that boss.

*Rule 2*. The second rule is that you must not try to handle too many people. There is no set number that one supervisor can handle. It depends on such factors as time, type of job, difficulty of work, and concentration of personnel. If the job is such that your employees work close together, you may be able to handle 15 to 20 people; but if the job is scattered, four or five may be enough.

*Rule 3*. The third rule of good organization is that you must be given the authority to get the job done. Nothing is harder on morale than to give supervisors a job and then tie their hands by not giving them any authority. If you give people the leadership to get a job done, you should also give them the authority to coordinate the work with other shops. You should give them the authority to get supplies and to draw the tools necessary for the job.

*Rule 4*. The fourth rule in organizing is that every person must answer for their own work. Supervisors must be responsible for their own jobs, which includes the work of their workers. They answer to their bosses for the work of their organizations. Of course, the workers in their organization must answer to them. Every person is responsible for his or her job to the next person above them.

**Exercises (047):**

1. Match the following rules for organization in management principles to the appropriate situation below by placing the letter of the rule in the space provided.

   a. Each person must have only one boss.
   b. One person should not be given too many people to supervise.
   c. Authority must be given to get the job done.
   d. Each person must answer for their own work.

____ (1) You are the supervisor of a very large interior electric shop. There are 30 people altogether with 6 assigned to the alarm crew, 10 to the minor construction crews, 4 on equipment maintenance, 5 on relamping, and 4 people working on service calls and job orders. You designate the ranking person of each crew as crew leader. You are in direct supervision of these crew leaders and they are in direct supervision of the people in their crew.

____ (2) In the crews mentioned in number (1) above, each crewmember is only responsible to the crew leader and receives instructions and directions from them only.

____ (3) Each crew leader is given the authority to carry out his or her jobs and draw the necessary supplies for the jobs.

____ (4) Each crew leader holds his or her people responsible for their work, you hold the crew leaders responsible for their crew's work, and your boss holds you responsible for your shop's work.

**048. State ways of giving directions so they are well received and understood and specify when oral and written directions should be used.**

**Directing Work.** Directing work is a vital activity required between the time you prepare for operations and the time that actual operation starts. It consists of issuing instructions to subordinates about what to do and how and when to do it. Good performance depends upon a clear understanding of what is to be done between the workers and the supervisor. This understanding is often quite hard to achieve since the directions given may mean one thing to the supervisor and something else to the worker.

*Two-way process*. When you give work directions, you must know your subordinates' capabilities and workloads. You need to consider the equipment, material, and supplies needed to do the work. If you ignore these factors, it will cause lost time and disgruntled workers. Maybe you can recall some examples of poorly planned work assignments. When you give an assignment, make sure that it is understood. If the workers do not understand, they should let you know. This interchange of information leads to better relations and a better view of the situation for both you and the workers. Thus, the directing of work should be a two-way process that results in improved performance and harmonious relations. To make sure that your directions are understood, ask the workers to repeat their instruction by telling you what they are going to do. Also, ask them if they have any questions. Use of the two-way process in directing helps you stop confusion and lost manhours, and insures that the worker's efforts go toward completing the job that needs to be done.

*Giving good directions*. Many of the directions you give come from regulations, manuals, and operating instructions. Use these controlling directives as guides when you prepare your work directions. However, there are some situations that call for decisions and directions that are not found in formal directives. In these cases, you must develop your own directions with the use of organizational objectives and good judgment as your guides. The way you give directions to workers will vary. Sometimes you must demand immediate action. In other situations, a suggestion of what is to be done is enough. For example, if you are giving directions to a newly assigned person, use the request type of direction. Later, you may need to alter the type of direction you give this same person because this person responds best to the demand or direct type of direction.

With experienced workers who are willing and cooperative, you get good results with a suggested or implied form of direction or by asking for a volunteer. With experienced workers, the demand type of direction often causes worker resentment and tense relations.

*Oral and written directions*. Directions can be expressed orally or in writing. Each method has its advantages. For example, it is foolish to give short, simple directions in writing. It is also poor supervision to give long, complicated directions orally. It is sometimes necessary to give oral directions to supplement written directions. This is true when you must explain a situation, when you wish to provide an opportunity for questions, or when you must be absolutely sure that a directive is understood.

To make sure that your instructions are clear and will not cause confusion or misunderstanding, be sure they answer the questions of "What? Why? When? Where? Who? and How?" If all of these questions are answered in your directions, the chance of misunderstanding is greatly reduced.

There are times, even when all of these questions are answered, the directions may not be understood because you assume that the worker has a full knowledge of the subject. As a result, you may use words that are too technical or too complex, you may not be specific enough, or you may include too little information. There are other times that your instructions may answer the six questions but turn out to be too long, too complicated, or not logically arranged. They may make the work seem unduly complicated, or may set up such vague guidelines that no one knows what is to be done. You must, therefore, not only be sure that all necessary information is included, but also must check the language used and how practical your directions are.

*Attitude of the directors*. It is not enough to be sure that the directions for doing a job are complete. The attitude of the individual who gives these directions is also important. For example, your supervisor may have asked for a recount of all the parts in bench stock. The supervisor may have finished the request with a remark such as, "Take care of it as quickly as you can, so that we can get on a job that is worth doing. Here's a copy of the count you made last week, if you want it."

It is not hard to picture what the attitude of anyone assigned to the preceding job is going to be. If the supervisor thinks it is a waste of time, the worker has little interest in the job and will do it carelessly. Both supervisors and workers must believe in the importance of the work they are doing if they are to do it well and enjoy doing it.

*Duty rotation*. Supervisors, while directing the operation of their units, should make it a point to rotate the duties of their people. A change of duty is often of value since it may keep workers from getting bored with what they are doing. It also gives you a chance to spread the less desirable jobs around so that one or two people do not get stuck with them. And, of course, rotation is an important part of upgrade training. It gives trainees a chance to be trained and get experience on all tasks for which they are responsible. An added benefit of rotation is that it gives you skilled persons who can do essential jobs when some of your people are gone. An example of how this works would be for you to assign one of your people to help you with the paperwork. This arrangement serves two purposes. It fulfills some of the supervisory and management training requirements for 7-level trainees and, at the same time, you are getting an assistant who can free you from spending so much time in the office.

**Exercises (048):**

1. State the reason that directions given by the supervisor do not always get carried out.

2. Specify how you can be sure that your directions have been understood.

3. Where do many of the directions used to guide your workers come from?

4. State two things you should use as guides when you must develop directions for your workers.

5. State the type of direction that is inferred in each of the following examples.
   a. "Sergeant, would you repair that hole?"
   b. "It would help if we removed this before we repair it."
   c. "Airman Jones, replace that unit."
   d. "Who is willing to stay late so we can get this job done?"
   e. "Sergeant Thomas, there seems to be a short between "C" phase and neutral."
   f. "Would you complete the entries on this form for yesterday's operation?"

6. State the conditions under which written directions should be prepared.

7. Why is it necessary to give oral directions at times in addition to written instructions?

8. State the questions you must answer when you prepare directions.

9. List five things that may keep your directions, even though they answer all the pertinent questions, from being understood.

10. State how the attitude of the person giving directions can affect the outcome.

11. List three benefits of rotating duty assignments.

**049. Differentiate between good and bad approaches to human relations.**

**Foundation for Good Human Relations.** Human relations on the job are a major and sensitive responsibility of the supervisor: you are completely aware that there are differences among human beings such as sex, race, background, and creed. You should know that people consider their jobs as their careers. They expect such things as a fair evaluation of their performance, equal opportunity to get ahead, and greater responsibilities to do important tasks and to have new job experiences. They desire status, the feeling of importance, and the desire to belong to a group. They also want economic and emotional security.

When workers find their status or pay check threatened, they know that something is wrong. They are more likely to accept change if you prepare them for it. You should try to keep a calm environment for people to work in. Keep rumors down by keeping your workers informed.

*Let workers know where they stand.* All workers need to know how they are getting along if they are to be happy and satisfied with their jobs. This includes whether workers know they are doing a good job or not. How can you do this? First, you can take an interest in your workers and get to know each one personally. Secondly, you can have periodic talks with each worker and see that each knows the job requirements. How often you contact your workers and how close the personal relationship that you maintain depend upon the individual work situations. Remember, there is a delicate balance between overfamiliarity and friendship. You must use good judgment or risk severe criticism that damages both morale and production in your unit.

*Give credit when due.* Recognizing individual effort is another technique that aids you in maintaining good job relations. Experience has proved that this technique gets good results, and supervisors who ignore it create problems such as loss of interest among their workers. But, knowing the technique and knowing how to put it to use are two different things. Giving credit when due is a good idea—but how do you do it? There are many ways. Here are some of them: (1) give workers a pat on the back and a little praise when they do a good job; (2) use letters of appreciation and commendation; (3) recommend outstanding performance ratings; (4) encourage the use of both the military and civilian suggestion programs, which can result in cash awards or other forms of recognition for improvements developed by your people; and, (5) recommend deserving personnel for promotion, upgrading, and better assignments.

*Inform workers in advance.* You need to inform your workers, of changes that affect them in advance. You can do this by personal contact with the individual, by written notices or bulletins, or by informal meetings and discussions. The last method is good, but calling workers together in a meeting to present a chan does not automatically win their support and approval. You must get their interest and participation. If possible, get the workers in on the planning for the changes. Encourage them to contribute their ideas and "pitch in" to meet the problem. The supervisor's attitude and conduct, in general, greatly influences the workers' willingness to cooperate.

*Gain the workers' confidence.* Take a personal interest in each worker; be friendly, helpful, and fair in your dealings; encourage the workers to come to you with their problems, and take action on their problems if possible.

When properly used, these techniques can be of great assistance to you. But remember, "No two people are exactly alike." You must get to know your workers and understand their individual differences and needs. Study each individual. Learn the personal interests and problems of each worker and know what his or her reactions will be. You can then treat each worker as an individual.

**Exercises (049):**

1. Mark the following statements with a "G" for good techniques of human relations or "B" for bad techniques of human relations.

a. ____ Do not bother a worker who is doing a good job.
b. ____ Get to know each worker personally.
c. ____ Have short periodic talks with workers to be sure they know their job requirements.
d. ____ Check on what your workers are doing several times a day.
e. ____ Stop and "shoot the breeze" with your workers frequently.
f. ____ Get to be good buddies with at least some of your workers.
g. ____ Make sure you praise a worker who does a good job.
h. ____ Have workers turn in a suggestion if they come up with an improved way of doing a job.
i. ____ Do not be afraid to give exceptional workers outstanding performance ratings.
j. ____ When a change is needed, decide on the change and then make it.
k. ____ Ask your workers for suggestions when you find current procedures are not getting the work out on time.
l. ____ Try to treat each worker the same way the worker treats you.
m. ____ Don't get involved with the problems of workers unless they ask you for help.

**050. List methods you should avoid when solving a problem and specify the steps to take to solve a problem.**

**How to Handle a Problem.** We are surrounded with problems. Some are small; others are large. Some maybe simple; others are so complex that there seems to be no way to solve them. Fortunately, the Air Force has developed tried and true procedures which work in solving 99 percent of the problems that you are apt to encounter on the job. Unfortunately, some supervisors have not studied these methods. Instead, they use methods of their own.

*The wrong way.* There are six methods used to face problems which almost always end in disaster. These are shown in Figure 3-1, "How Sgt Blow Faces Problems." Believe it or not, some supervisors, and individuals too, use one or more of these methods when faced with a problem. Sgt Blow, in Figure 3-1, ignores the problem. He also uses method number 4 (he runs away very often during duty hours to the NCO club). A supervisor should be on the job during duty hours, not goofing off. You can see by his shape that Sgt Blow often uses method number 6. People who can't solve their problems can very easily fall into the bad habit of overeating, overdrinking, or taking drugs. In the figure, you can see how important Sgt Blow thinks he is. He is the big man with the big cigar who looks down his nose at the little man; no doubt Sgt Blow's unit is like a sinking ship. The tombstone, in the figure, is the result of using those unwise methods of problem solving. His section is rated unsatisfactory and Sgt Blow is blown away, but he never learns that he is the reason why. When asked why he lost his job, he uses method number 3 and blames the people who worked for him as the reason for his section's failure.

*The right way.* The procedures you should use to solve problems are summarized in Table 3-1, How to Handle a Problem. Notice that the table is made up of five main steps. These steps are subdivided into many substeps. Study these steps to problem solving and use them as you solve the problems that evolve around you.

**Exercises (050):**

1. List six methods to avoid when you must solve problems. These steps do not have to be in any order—all are equally bad.
   a.

   b.

   c.

   d.

   e.

   f.

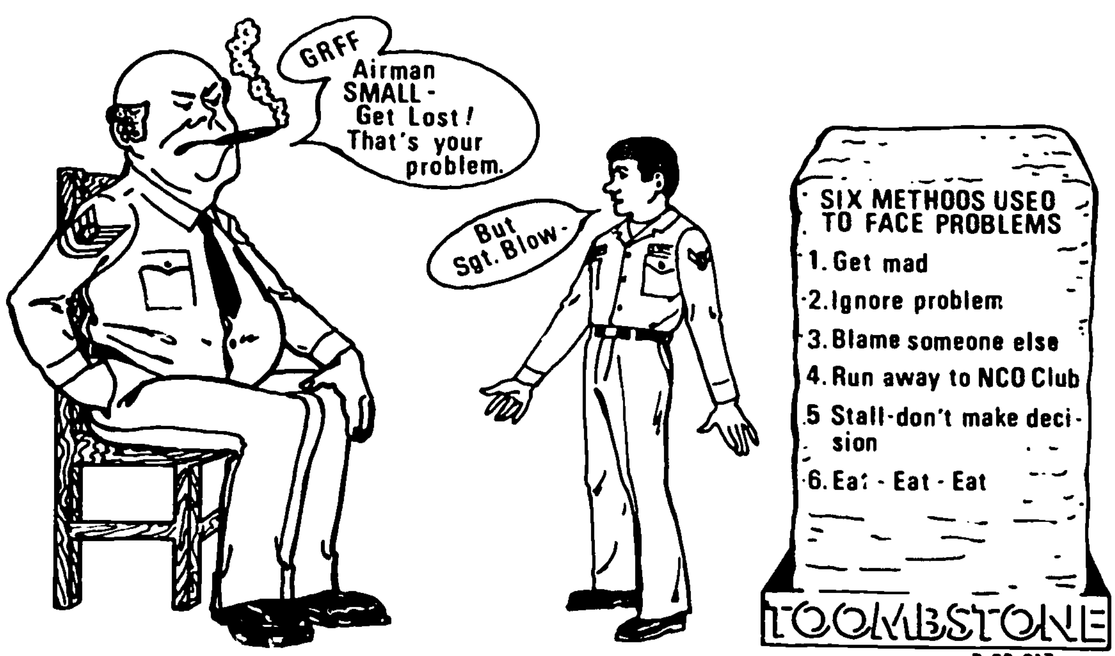


Figure 3-1. How Sgt Blow Hart faces problems.

2. Indicate the problem solving step from Table 3-1 during which the actions occur by entering the proper letter in the space provided.

Problem Solving Steps

a. Define the problem.
b. Get the facts.
c. Weigh and decide.
d. Take action.
e. Check results.

____ (1) Consult with other workers.
____ (2) Act on selected solution.
____ (3) Must be stated in specific terms.
____ (4) Analyze the facts.
____ (5) Review work records.
____ (6) Correct a faulty procedure.
____ (7) Establish relationship between facts.
____ (8) Correct any obvious weakness immediately.
____ (9) Be careful of preconceived ideas.
____ (10) Leads to setting objectives.
____ (11) Select the action to take.
____ (12) Observe job being done.
____ (13) May have overlooked a pertinent fact.

TABLE 3-1
HOW TO HANDLE A PROBLEM

1. DEFINE THE PROBLEM.
   a. What is the real problem.
   b. Write it on paper.
2. GET THE FACTS--ALL THE FACTS.
   a. Review the record.
   b. Find out what rules and regulations apply.
   c. Talk with individuals on both sides.
   d. Get opinions and feelings.
   e. Be sure you have the whole story.
3. WEIGH AND DECIDE.
   a. Fit the facts together.
   b. Consider their bearing on each other.
   c. What possible actions are there?
   d. Check practices and policies.
   e. Consider the objective and the effect on each individual or group and on work unit.
   f. Don't jump to conclusions.
4. TAKE ACTION.
   a. Are you going to handle this yourself?
   b. Do you need help in handling the situation?
   c. Should you refer this to your supervisor?
   d. Watch timing of your action.
   e. Don't pass the buck.
5. CHECK RESULTS.
   a. How soon will you follow up?
   b. How often will you need to check?
   c. Watch for changes in output, attitudes, and relationships.
   d. Did your action help work output?

PREVENT THE DEVELOPMENT OF PROBLEMS BY ELIMINATING THE CAUSES

BA-044

**051. List qualities you should try to instill in your workers and in given situations, distinguish between good and bad counseling principles.**

**Counseling Principles.** As a supervisor in the Air Force, you must have a basic understanding of counseling and guidance. This is because you are required to deal with people. You, as a counselor, must be able to interpret and explain the counselee's actions in terms of motive or cause if you expect to help the counselees understand themselves and solve their problems. To achieve this, you must be on the alert for causes. Surface effects like "coming in late" and "will not work" only indicate that a worker has a problem. They indicate that you must dig deep and try to find out what the cause is. In discussing the problem with the worker, you must ask yourself, "What is the basic cause, reason, motive, or consideration that has made this person behave as he or she does?"

When you learn the principles of counseling, you avail yourself of a method which helps you put your finger on the real problem. It also gives you a clue to the answer to the problem. And better still, you gain an insight into the causes of potential problems and the key to problem prevention.

People must make decisions one way or the other every day of their lives. The tossup type of decisions are the hardest to make. Airman Joe Watts was on KP and had to separate truckloads of potatoes into a good pile and a bad pile. When he asked his supervisor to relieve him from that duty, he said, "I don't mind the work, but those decisions are driving me nuts. I can't get them off my mind and can't go to sleep thinking about them. My production has dropped 50 percent."

Some people have the ability to make decisions that improve their way of life. Others make decisions that are self-destructive. As a supervisor, you must help the self-destructive-type individuals learn how to make decisions that will improve their way of life and their image of themselves. When they learn how to make proper decisions, their self qualities will change from negative to positive. Your purpose in counseling should be to produce the following positive self-qualities in your workers:

- Self motivation.
- Self understanding.
- Self responsibility.
- Self directivity.
- Self productivity.
- Self satisfaction.

Counseling and "chewing out" are not the same thing. Why not? Because a "chewing out" causes resentment and frustration among the "chewees" and seldom improves their attitudes or production. On the contrary, a bawling out usually causes anger, a negative attitude, and a reduction of production.

The essence of counseling is the ability to mentally and emotionally put yourself in the place of the person you wish to counsel. You must gain an understanding of this person's problem by looking at it as though you were seeing through his or her eyes.

This viewpoint is not an easy one to acquire, but it is basic to true counseling. It is called empathy. Empathy in no way means "sympathy" or "coddling." After all, remember that you are dealing with adults, not children. Whatever they have or have not done, they want to be treated as adults.

Certain principles are followed by every good supervisor-counselor. Probably the most successful of these principles, which you too should learn and practice, are these. The order in which they are listed is not, in itself, especially significant.

*Counseling Principles*

- Respect each worker.
- Act friendly—smile.
- Listen to worker.
- Do not threaten worker.
- Do not argue with worker.
- Encourage worker to talk about the problem.
- Let worker express attitudes and emotions.
- Relieve worker from fears and anxieties.
- Help worker to help themselves.
- Be patient and understanding.
- Stress mutual cooperation.
- Stress joint responsibility.
- Use problem-solving methods.
- Do not gossip about problem.

**Exercises (051):**

1. List self-qualities you, as a supervisor, wish to produce in your workers.

2. Answer true or false. Counseling is chewing out a person for something he or she has done wrong or something he or she has failed to do. State the reasons for your answer.

3. In the following exercises place an X in the space provided for bad counseling principles.

____ a. MSgt Jones pounds the table when telling A1C Jack Smith about his error.
____ b. Supervisor Kelley is firm but friendly.
____ c. SSgt Judy Sand tells her workers that they should be seen but not heard.
____ d. TSgt Bills says, "Let them talk so you can get the goods on them."
____ e. Do not argue with worker during a counseling session.
____ f. Tell the boys what Amn Joan Grey said during her interview.

**052. Distinguish between situations in which you should counsel a subordinate and those in which you should not counsel, and list the steps to follow in solving a given personnel problem.**

**Problems of the Individual and the Supervisor.** An individual may be a poor producer on the job because of personal problems. These problems can include, but are not limited to, overspending, excessive drinking, and frustration in not being able to reach a goal, among others. Obviously, workers who have problems which they are not able to manage may bring their problems onto the job with them. If they do so, they cannot concentrate properly on their jobs, because their minds will keep going back to their personal problems. This is where you come in as a supervisor. You can—and should try to—help these people by trying to find out the real reason for their low productivity. Besides, by working to help such a subordinate, you will be helping the productivity of your whole shop. In any event, when you dig deep, you will usually find that what appears to be the problem (effect) is not the real one (cause). Consider, for example, Airman Johnny Smith, who is making many errors. On the surface, it may seem that he is just a lazy fellow—one who doesn't really care. Actually, however, his true problem is the collector who is hounding him for falling behind in the payment of his bills.

As a supervisor, you don't have to be a "know it-it-all" to solve such personal problems. Each Air Force Base has referral agencies that specialize in various fields. Therefore, you can refer the troubled worker to the appropriate agency. Some of these agencies are the Legal Office, Red Cross, Social Actions, Education Office, Drug Information, Chaplain, Career Advisor, and Family Services. Still, it is your responsibility as a supervisor—no one else's—to find out the real, underlying problem. An important, fundamental tool which you can use to do this is the counseling interview.

**The Counseling Interview.** The interview is the heart of the counseling process. Why? Because it is, usually, only while the counseling interview is in process that the counselor and counselee meet directly, personally, and jointly to discuss and attempt to resolve—or at least alleviate—the counselee's problem. Since good interviewing is essential to effective counseling, every supervisor should be familiar with its basic principles.

These principles include preparing for the interview, conducting the interview, closing the interview, evaluating the success of the interview, recording the interview, and following up on the interview.

*Preparing for the interview.* In getting ready for the interview, you should collect all the information possible about the counselee. You should choose a nice quiet place to meet where there are no interruptions and you should get yourself mentally ready.

*Beginning the interview.* When you begin the interview, it is important that the counselee be provided with relief from distrust, tension, and insecurity. To this end, certain techniques are valuable.

*Establishing rapport (harmony).* "Rapport" can be defined as that atmosphere of understanding, mutual trust, and confidence that enables people to work together effectively. Regarding rapport, the initial meeting between the counselor and counselee is often of crucial importance. You can "help things along" by rising to your feet, smiling, extending your hand when the situation demands, and stepping forward to meet the counselee. If you do these things sincerely, you will go a long way toward gaining the confidence and overcoming any defensiveness the counselee may feel at the outset.

*Conducting the interview.* During the interview, listen attentively to the counselee. Counselors must listen! This is basic. It is likely that they will learn very little by talking themselves, but they may learn a great deal about people by listening to everything they have to say. In fact, numerous studies made in public schools and in private industry have shown that one of the most frequent errors made by professional counselors is that they talk too much and listen too little. After all, communication is a two-way process, but the most important input is that of the counselee. As the interview develops, you should follow this four-step procedure:

(1) Analyze the problem and situation thoroughly.
(2) Define the limits of the problem.
(3) List any referral sources needed.
(4) Outline a course of action for solving the problem.

*Closing the interview.* If it is possible, have the counselee summarize the interview. If the counselee is cooperating in the counseling process, you may succeed in getting him or her to summarize what has been learned. Still, if the counselees fails to cooperate, you may need to make the summary yourself.

*Evaluating the success of the interview.* Immediately after the interview, you can take stock and quietly congratulate yourself on having been successful to some degree if the counselee leaves with:

*a.* A plan of action.
*b.* A feeling of accomplishment.
*c.* The feeling that he or she may return at any time.

In the final analysis, the best criterion for evaluating the success of any interview is the results obtained. The results are beneficial when the counselee's problem no longer exists or when a satisfactory adjustment has been made, so that the condition no longer negatively affects the person's achievement.

*Recording the interview.* Use the appropriate evaluation form to record information that you get during the interview. Usually, it is considered best not to make notes during the interview. But immediately after the interview, you should record the information in some way so that you will remember all the points covered.

*Following up the interview.* At this point, you DO what you told the counselee you would do to follow up on progress. Frequently counselors check just superficially, noting that some improvement was made. This will not suffice. Your follow up should be a thorough investigation to determine whether or not the counselee's actions are the ones agreed upon during the interview. When following through in this manner, you may find a need for further consultation. Then you can assist the counselee to continue on a satisfactory course of action.

**Exercises (052):**

1. Write T for true or F for false beside each letter-coded item related to the problems of the individual and the supervisor which can lead to the setting up of a counseling interview between them.

____ a. Workers with problems that they can't manage may bring them on the job with them.
____ b. As a supervisor-counselor, you can help workers with problems most by discovering the real reason for their problems, then help them resolve the problems.
____ c. It helps for supervisor-counselors to be "know-it-alls" as they try to solve their workers' personal problems.
____ d. Supervisors can refer troubled workers to various referral agencies on base who are better able to help them resolve their problems than the supervisor.
____ e. In any case, it is the supervisor's responsibility still—no one else's—to find out the real, underlying problem.

2. Read the following problem situation, which is based on a personal problem of A1C Jim Johnson who works for you. On a plain sheet of paper, list the steps you will follow to solve this problem.
   Situation: You are supervisor of the electric shop. A1C Johnson works for you. His records indicate that he is highly qualified to do the job. But, lately, he has been wearing wrinkled uniforms and often needs a haircut and shave. He is also performing below his capability, seems sleepy most of the time, and complains of having too many bills to pay. How are you going to handle this problem?

**053. Specify important considerations in determining and using performance standards.**

**Performance Standards.** Workers have a right to know what their supervisors expect of them. They should be told

how their work is to be judged. The purpose of performance standards is to define the quality and quantity of work that must be put into a job for it to be satisfactorily completed.

*Determining standards*. Performance standards should be realistic and practical. Quite often people have difficulty when they set up standards because they put too much emphasis on the operating details of the job rather than on the results. The objective should be to set levels of performance that will get the unit's mission done. Reasonable standards stimulate people to work. Workers are neither overloaded nor underloaded. Thus, when workers complete a job that is based on a reasonable standard, they have a sense of satisfaction of a job well done. When workers are overloaded, there are accidents, errors, fatigue, high turnover of personnel, resentment, and slowdown. The situation is just as bad when workers do not have enough to do. The results here are usually mischief, too high a cost of operation, grievances, and absenteeism. The factors of worker overload and underload are important when you set up the level of performance standards.

Performance standards for each work operation must describe what is acceptable performance. They should be set at the level of performance that can be expected of any qualified, competent worker. Workers become frustrated and will quit trying to reach a goal if the performance level is set too high. The requirement must be at a level that can be reached by average workers. There should be room for exceptional workers to perform above the requirement.

Do not base the requirement level upon the performance of the worker who is now assigned to the position. This would assume that the worker is meeting all the requirements of the position at an acceptable level. If such a worker has unusually high qualifications, it will penalize other workers' outstanding performance as being only satisfactory, and penalizes future workers who are competent but not outstanding by rating their performance as unacceptable. On the other hand, if the worker's performance is actually not good, the established level of satisfactory performance will be too low.

Another thing that you must consider when you are determining performance standards is the fact that all workers do not produce an identical amount and quality of work. Rather, there is a range of performance which should be considered as acceptable. Performance that is below this level is below average and may possible be unacceptable. Performance that is above this level is considered above average and may possibly be outstanding. The established range should be realistic.

You can use the following procedures to set up performance standards:

*a*. Select the tasks or major work factors of the job.

*b*. Decide tentatively what is reasonable to expect as to:

(1) Quantity of results in a given time.

(2) Quality of results in terms of how well the job must be performed.

(3) Manner of performance.

*c*. Discuss tentative requirements with:

(1) Workers assigned to the job.

(2) Your supervisors.

(3) Other supervisors who determine requirements for the same type of operation.

*d*. Check the possible effect of existing requirements in relation to:

(1) Trade or craft requirements.

(2) Management data.

(3) Requirements of higher echelons.

*e*. Review and formulate firm requirements that are fully understood by all workers affected.

*Using performance standards*. Performance standards must be used to be of any benefit. You must weigh the workers' performance continually against the standards and discuss it with them from time to time. You must then take action consistent with the workers' performance by (1) giving recognition to workers who exceed the standards, (2) helping workers who are below the standards by added training or other appropriate means, and (3) motivating workers who are doing acceptable work to get them to perform better if they are capable.

Several distinct benefits can be realized from the proper use of realistic performance standards. They set what is the least acceptable production goals for each worker. These goals help to give your workers a better attitude toward the work situation because they tend to create greater job satisfaction. Other advantages are these: they provide a sound basis for estimating future work capacity; they provide data for planning, organizing, and assigning work; they provide a basis for determining who needs more training and how much; and they provide a sound basis for personnel actions, and formal ratings such as APR's.

**Exercises (053):**

1. State the purpose of setting up performance standards.

2. Give two precautions that should be taken when setting up performance standards for a job.

3. If standards are set up that cause workers to be overloaded, what effects are likely to show up on the job?

4. What usually happens when job standards are set too low?

5. State the level of performance that should be set for a job.

6. Why should you be careful not to use the worker now doing the job as your standard when setting performance standards?

7. State how you should allow for the fact that all workers do not produce the same amount and quality of work when you develop performance standards.

8. When setting up a job performance standard, whose opinions should be considered?

9. Once you have established performance standards, how do you benefit from them?

10. List four benefits that you can gain from the proper use of realistic performance standards.

**054. State the procedures used to get valid performance ratings to evaluate the performance of an airman and the requirements for submitting Airman Performance Reports.**

**Evaluation of Subordinate Personnel.** You as a supervisor must be willing to accept all the responsibilities that go with supervision. Often, one of the more difficult of these responsibilities is the evaluation of your personnel and the preparation of performance ratings. Many supervisors dread having to carry out this part of their jobs because, in a good deal of cases, the results leave much to be desired. On occasions, tempers flare, words fly, and friendly working relationships that are needed for goc performance are lost or disrupted.

Some of the difficulties involved in the rating of personnel are relieved if the supervisor has prepared for the task. Probably the first and most important way to prepare your people for rating is to make sure that they understand the performance standards expected of them. When this aspect of their job is made clear, early in their assignment, they are not too apt to plead ignorance at rating time. An occasional suggestion or reminder is useful when some individuals tend to relax their standards. Also, an interview or counseling session proves valuable at times to improve attitudes, performance, or interest in becoming more skillful.

**Airman Performance Reports (APR's).** The basis for rating is observation, evaluation, and reporting. First, it is necessary that the performance of the individual be observed. These observations should be made over a long enough period of time to be sure that typical performance is observed. This consists of direct observation of the person's behavior, performance of duty, and work quality. If you can not make direct observations, you should try to get meaningful information from as many sources as possible.

Following your observations, you must evaluate the typical performance of the individual against an acceptable standard. Do not place too much emphasis on isolated instances of either poor or outstanding behavior. The significance of the event, as well as how often it occurs, must be weighed, to help you make up your mind on how well it represents the total performance. Each person must be judged in comparison with other persons who serve in the same grade and job.

After you have made your observation and evaluated the individual, you can write the performance report. The report should be made as objective as possible on the basis of your observations.

Performance reports are normally required when there has not been a report submitted for 1 year. Reports are also required when there is a change in the rating official, or when the individual's performance requires a referral report. Prior service enlistees must have an APR prepared 120 days after enlistment. Submission requirements are outlined in Table 3-1 of AFR 39-62, *Noncommissioned Officer and Airman Performance Report.*

Reports are to be made by a rater called the reporting official. This official is a commissioned officer, noncommissioned officer, a senior airman, or a civilian in the grade of GS-4 or higher. The rater is usually the ratee's immediate supervisor. Indorsements generally follow the chain of supervision. That is, the first indorser is the rater's rater, the second indorser is the first indorser's rater, and so on.

Performance reports are not to be used as a means of, nor as a basis for, disciplinary action. The reports become a part of the personnel records kept on an NCO or airman for administrative purposes. They contribute information concerning the individual's duty performance, which, with the rest of the individual's personnel record, is used as reference to such personnel actions as promotion, classification, and assignment.

*Referral report.* A report that contains any ratings in the lowest block (excluding Not Observed) in any one item of section III or an overall evaluation of 0 or 1 in section IV is a referral report. Any comments in the APR, or attachments, that refer to conduct incompatible with Air Force standards of personal conduct, character, or integrity are also referral reports. Referral reports can also be written for below standard duty performance, dress, bearing, judgment, leadership, supervisory responsibilities, or nonrecommendation for promotion or reenlistment. If there is a doubt as to whether the APR is a referral report, it should be made a referral report.

*Outstanding report.* An APR containing an entry by any rating official in the highest rating box (box 9) in section IV is considered outstanding. The APR rating reported by the final indorsing official is the rating that goes into the computerized Personnel Data System (PDS).

**Exercises (054):**

1. Why do many supervisors find rating their personnel a difficult job?

2. How can you prepare your workers for rating?

3. What are the basic requirements to develop a valid rating?

4. How should your observation of the ratee's performance be made for best results?

5. Explain why you should not rate the worker on isolated observations.

6. Who prepares the APR on an airman?

7. When would a ratee be shown an APR before it is completed?

8. When are APR's normally submitted?

9. What type of APR is it when the overall rating is 1?

10. If the rater rates the individual as outstanding (9) and the third indorsing official (final) rates the individual as 8, what is the computerized rating of the APR?

**055. State the procedures that apply to the preparation of APR's and identify the correct form to use.**

**Forms Used.** The forms used in preparation of an APR will depend on the airman's grade. The forms to be used are as follows:

*a.* AF Form 909, Airman Performance Report, is used to rate Senior Airman (SRA), Airman First Class (A1C), Airman (Amn), and Airman Basic (AB).

*b.* AF Form 910, TSgt, SSgt, Sgt Performance Report is used for Technical Sergeants (TSgts), Staff Sergeants (SSgts), and Sergeants (Sgts).

*c.* AF Form 911, CMSgt, SMSgt, MSgt Performance Report, is used for Chief Master Sergeants (CMSgts), Senior Master Sergeants (SMSgts), and Master Sergeants (MSgts). **Instruction.** For instructions on how to fill out these forms refer to Chapter 4 of AFM 39–62. Figures 3-2, 3-3, 3-4, and 3-5 show forms you will use, along with a statement in each block of the form, and will give you an idea of what information to fill in. It is relatively simple to fill out but for specific instructions or questions, always refer to the regulation as a guide.

Type the APR if possible. Otherwise, print or legibly write the entries in black or dark blue ink. No corrections or erasures are permitted in Section III and IV of the report. Corrections or erasures made on other parts of the report are authorized as long as there aren't too many. If the change changes sentence structure or meaning, it must be initialed by the evaluator who makes the change.

**Letter of Evaluation (LOE).** Sometimes a rater does not have a chance to fully observe a subordinate's performance and personal qualities during the reporting period. For example, the rater may change and there was not enough time passed since the closeout date of the last APR to require the submission of another APR. Another example would be when duty was performed under the supervision of someone other than the rater for part of the reporting period. In either case a LOE is submitted. Conditions that determine when to obtain or write an LOE are in Table 3-4 of AFR 39–62 along with rules that apply to LOEs. One of the more common rules that may apply to you is that LOEs must be submitted if the period of supervision is more than 60 days but less than 120 days.

LOEs along with additional indorsements and continuation sheets are submitted on AF Form 77, Supplemental Evaluation Sheet. An example of Af Form 77 is in Figure 3-6. Use the same procedures to fill out this form as you do on the APR forms.

**Exercises (055):**

1. Place the form number, 909, 910, 911, or 77, in the space provided to show the form used for the situation described below.

____ a. An airman who has been on active duty for 12 months is due an APR.
____ b. Major Neal is required to write SMSgt Blackman's APR.
____ c. You write SRA Watt's APR.
____ d. SRA Brown's APR is due on March 5 and he will be promoted to Sgt on March 1.
____ e. Sgt Anderson has been under your supervision for 73 days and has received a PCS assignment.

**I. RATEE IDENTIFICATION DATA** *(Read AFR 39-62, Vol I, carefully before completing any item.)*

| 1. NAME *(Last, First, Middle Initial)* | 2. SSAN | 3. GRADE |
|---|---|---|
| Watts, Betty J. | 000-00-0000 | A1C |

| 4. ORGANIZATION, COMMAND, LOCATION AND PAS CODE | 5. PERIOD OF REPORT AND SUPERVISION | | 6. REASON FOR REPORT |
|---|---|---|---|
| 35th Cmbat Support Group (TAC) George AFB California GBOTFD4J | FROM 12 Dec 77 | NO. OF DAYS 190 | CHANGE OF RATER |
| | THROUGH 13 Aug 78 | | ANNUAL |
| | | | X DIRECTED BY HQ USAF |

| 7. PAFSC | 8. DAFSC | 9. CAFSC |
|---|---|---|
| 81150A | 73250 | 73250 |

**II. JOB DESCRIPTION:** Wing/Base Records Clerk. Responsible for the filing and maintenance of approximately 400 Unit Personnel Records Groups. Prepares "Statements of Service". Conducts records reviews. Assists NCOIC in controlling access to Unit Personnel Records Groups.

**III. EVALUATION OF PERFORMANCE**

| Factor | | N/O | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. PERFORMANCE OF DUTY: Consider the quantity, quality, and timeliness of duties performed as described in Section II. | RATER | | | | | | | | | X | | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 2. HUMAN RELATIONS: Consider how well ratee supports and promotes equal opportunity, shows concern and is sensitive to needs of others. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 3. LEARNING ABILITY: Consider how well ratee grasps instructions, communicates (oral and written), and understands principles and concepts related to the job. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 4. SELF-IMPROVEMENT EFFORTS: Consider how well ratee progresses in on-the-job training and in other efforts to improve technical knowledge and educational level. | RATER | | | | | | | | X | | | |
| | 1ST INDORSER | | | | | | | | X | | | |
| 5. ADAPTABILITY TO MILITARY LIFE: Consider how well ratee adapts and conforms to the requirements of military duties not directly related to the job. | RATER | | | | | | | | | X | | |
| | 1ST INDORSER | | | | | | | | | X | | |
| 6. BEARING AND BEHAVIOR: Consider the degree to which ratee's bearing and behavior on and off duty improve the image of Air Force airmen. | RATER BR | | | | | | | | | X | | |
| | RATER BH | | | | | | | | | | X | |
| | 1ST INDORSER BR | | | | | | | | | X | | |
| | 1ST INDORSER BH | | | | | | | | | X | | |

**IV. OVERALL EVALUATION**

How does the ratee compare with others of the same grade and Air Force specialty? Potential for promotion and increased responsibility are essential considerations in this rating.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| RATER | | | | | | | X | | | |
| 1ST INDORSER | | | | | | | X | | | |
| 2D INDORSER | | | | | | | | X | | |
| 3D INDORSER | | | | | | | | X | | |

AF FORM SEP 79 909 PREVIOUS EDITIONS ARE OBSOLETE.

**AIRMAN PERFORMANCE REPORT**
**(Airman Basic thru Senior Airman)**

Figure 3-2. AF Form 909.

| I. RATEE IDENTIFICATION DATA *(Read AFR 39-62, Vol I, carefully before completing any item.)* | | |
|---|---|---|
| 1. NAME *(Last, First, Middle Initial)* SELLMAN, JAMES S. | 2. SSAN 000-00-0000 | 3. GRADE TSGT |

| 4. ORGANIZATION, COMMAND, LOCATION AND PAS CODE | 5. PERIOD OF REPORT AND SUPERVISION | | 6. REASON FOR REPORT |
|---|---|---|---|
| 35th Cmbt Spt Gp (TAC)<br>George AFB California<br>GBOTFD4J | FROM 14 Aug 77<br>THROUGH 5 Jun 78 | NO. OF DAYS 222 | X CHANGE OF RATER<br>ANNUAL<br>DIRECTED BY |
| | 7. PAFSC 73270 | 8. DAFSC 73270 | 9. CAFSC 73270 |

II. JOB DESCRIPTION: Wing/Base, NCOIC, Records Unit. Responsible for insuring the accountability, maintenance and control of approximately 5500 Unit Personnel Records Groups. Schedules and conducts records reviews. Provides required support to the remaining units within the CBPO. Supervises eight personnel. Prior Duty: DAFSC - 73270, Wing/Base, NCOIC, Separations Unit.

III. EVALUATION OF PERFORMANCE

| Factor | | N/O | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. PERFORMANCE OF DUTY: Consider the quantity, quality, and timeliness of duties performed as described in Section II. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | | X |
| 2. HUMAN RELATIONS: Consider how well ratee supports and promotes equal opportunity, shows concern and is sensitive to needs of others. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 3. TRAINING: Consider how well responsibilities are discharged as an OJT supervisor or trainer and in other efforts to improve technical knowledge and educational level. | RATER | | | | | | | | | X | | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 4. SUPERVISION: Consider how well ratee supervises, leads, uses available resources, communicates (oral and written), and maintains good order and discipline. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 5. ACCEPTANCE OF NCO RESPONSIBILITY: Consider ratee's acceptance of responsibility for personal actions and those of subordinates. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 6. BEARING AND BEHAVIOR: Consider the degree to which ratee's bearing and behavior on and off duty improve the image of Air Force noncommissioned officers. | RATER | BR | | | | | | | | | X | |
| | | BH | | | | | | | | | X | |
| | 1ST INDORSER | BR | | | | | | | | | X | |
| | | BH | | | | | | | | | X | |

IV. OVERALL EVALUATION

How does the ratee compare with others of the same grade and Air Force specialty? Potential for promotion and increased responsibility are essential considerations in this rating.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| RATER | | | | | | | | | X | |
| 1ST INDORSER | | | | | | | | | X | |
| 2D INDORSER | | | | | | | | | X | |
| 3D INDORSER | | | | | | | | | X | |

AF FORM SEP 79 910 PREVIOUS EDITIONS ARE OBSOLETE. TSGT, SSGT, SGT PERFORMANCE REPORT

Figure 3–3. AF Form 910.

| I. RATEE IDENTIFICATION DATA *(Read AFR 39-62, Vol I, carefully before completing any item.)* | | |
|---|---|---|
| 1. NAME *(Last, First, Middle Initial)* TURVEY, DENNIS R. | 2. SSAN 000-00-0000 | 3. GRADE SMSgt |

| 4. ORGANIZATION, COMMAND, LOCATION AND PAS CODE | 5. PERIOD OF REPORT AND SUPERVISION | | 6. REASON FOR REPORT |
|---|---|---|---|
| 35th Cmbt Spt Gp (TAC)<br>George AFB CA<br>GBOTFD4J | FROM 14 Aug 77<br>THROUGH 13 Aug 78 | NO. OF DAYS 330 | CHANGE OF RATER<br>X ANNUAL<br>DIRECTED BY |
| | 7. PAFSC 81199 | 8. DAFSC 73299 | 9. CAFSC 73299 |

II. JOB DESCRIPTION: Wing/Base, NCOIC, Customer Assistance Section. Reviews and controls all incoming correspondence, establishes priorities, and ensures timely completion of all tasks. Administers casualty services and military and personal affairs programs. Exercises general management over three units: Customer Service Unit, Records Unit and Personal Affairs Unit. Supervises six personnel. Additional Duty: Squadron Security NCO.

III. EVALUATION OF PERFORMANCE

| Factor | | N/O | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. PERFORMANCE OF DUTY: Consider the quantity, quality, and timeliness of duties performed as described in Section II. | RATER | | | | | | | | | | | X |
| | 1ST INDORSER | | | | | | | | | | | X |
| 2. HUMAN RELATIONS: Consider how well ratee supports and promotes equal opportunity, shows concern and is sensitive to the needs of others. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 3. [illegible]ING: Consider how well responsibilities [illegible] discharged as an OJT supervisor or trainer and in other efforts to improve technical knowledge and educational level. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 4. EXECUTIVE ABILITY: Consider ratee's judgment, decisiveness, ability to communicate (oral and written), and effectiveness in supervising and leading. | RATER | | | | | | | | | | | X |
| | 1ST INDORSER | | | | | | | | | | X | |
| 5. ACCEPTANCE OF NCO RESPONSIBILITY: Consider ratee's acceptance of responsibility for personal actions and those of subordinates. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 6. BEARING AND BEHAVIOR: Consider the degree to which ratee's bearing and behavior on and off duty improve the image of Air Force noncommissioned officers. | RATER (BR / BH) | | | | | | | | | | | X |
| | 1ST INDORSER (BR / BH) | | | | | | | | | | | X |

IV. OVERALL EVALUATION

| How does the ratee compare with others of the same grade and Air Force specialty? Potential for promotion and/or increased responsibility are essential considerations in this rating. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| RATER | | | | | | | | | | X |
| 1ST INDORSER | | | | | | | | | X | |
| 2D INDORSER | | | | | | | | | X | |
| 3D INDORSER | | | | | | | | | X | |

AF FORM SEP 78 911 PREVIOUS EDITIONS ARE OBSOLETE. CMSGT, SMSGT, MSGT PERFORMANCE REPORT BE-911

Figure 3–4. AF Form 911.

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V. RATER'S COMMENTS FACTS AND SPECIFIC ACHIEVEMENTS: Illustrate the way the ratee typically carries out any duties whether assigned or not assigned. Do not recapitulate duties performed; tell how the ratee performs. STRENGTHS: Describe those positive aspects of the individual's performance deserving special note. RECOMMENDED IMPROVEMENT AREAS: Clearly specify whether references are to serious deficiencies, faults, bad habits, or to occasional tendencies. The value of such comments will be vastly increased if they include an indication of what progress, if any, has occurred as a result of bringing the weaknesses to the individual's attention before preparing the report. An entry under this heading does not require referral (paragraph 3-10) unless it contains comments of the type defined in paragraph 2-9c. EDUCATIONAL AND TRAINING ACCOMPLISHMENTS: Comment on any special training or courses of instruction the ratee completed or actively participated in during the reporting period. This also includes off-duty educational achievements. If applicable, comment on the manner in which the ratee discharges OJT responsibilities, whether as an OJT supervisor, trainer or trainee. SUGGESTED ASSIGNMENTS: Apply your evaluation of the individual for subsequent utilization. Be specific. OTHER COMMENTS: Include those comments required by paragraph 4-6b(2). Add any comments not covered above which add to the report and which are not prohibited by paragraph 3-12.

| NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND AND LOCATION | DUTY TITLE | DATE |
|---|---|---|
| RICHARD L. MURPHY, CMSgt. USAF<br>35th Cmbt Spt Gp (TAC)<br>George AFB, California | Asst Chief, Customer Assistance Section | 13 Aug 80 |
| | SSAN: 000-00-0000 | SIGNATURE: Richard L. Murphy |

VI. 1ST INDORSER'S COMMENTS ☐ CONCUR ☒ NONCONCUR

Indicate concurrence or disagreement with the report. Significant disagreement with ratings must be substantiated by specific comment. In addition, include any comments that will increase the value of the report.

| NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND AND LOCATION | DUTY TITLE | DATE |
|---|---|---|
| MICHAEL C. WHITE, GS-9, DAF<br>35th Cmbt Spt Gp (TAC)<br>George AFB CA | Chief, Customer Assistance Section | 15 Aug 80 |
| | SSAN: 000-00-0000 | SIGNATURE: Michael C. White |

VII. 2D INDORSER'S COMMENTS ☒ CONCUR ☐ NONCONCUR

Indicate concurrence or disagreement with the report. Significant disagreement with ratings must be substantiated by specific comment. In addition, include any comments that will increase the value of the report.

| NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND AND LOCATION | DUTY TITLE | DATE |
|---|---|---|
| ROGER S. SALISBURY, Major, USAF<br>35th Cmbt Spt Gp (TAC)<br>George AFB, California | Chief, CBPO | 15 Aug 80 |
| | SSAN: 000-00-0000FR | SIGNATURE: Roger S. Salisbury |

VIII. 3D INDORSER'S COMMENTS ☐ CONCUR ☐ NONCONCUR

THIS SECTION NOT USED

| NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND AND LOCATION | DUTY TITLE | DATE |
|---|---|---|
| | | |
| | SSAN | SIGNATURE: RSS |

Figure 3–5. Reverse of AF Forms 909, 910, and 911.

**I. RATEE IDENTIFICATION DATA**

| | | |
|---|---|---|
| 1. NAME (Last, First, Middle initial) Archer, Walter W | 2. SSAN (Include suffix) 000-00-0000 | 3. CURRENT GRADE TSgt |
| 4. DAFSC 73270 | 5. DUTY TITLE OR TITLE OF SPECIAL OR ADDITIONAL DUTY Wing/Base NCOIC, Records Unit | |

**II. TYPE OF REPORT** *(Check appropriate block in Part A.) (Complete Part B as required.)*

| | | | | | |
|---|---|---|---|---|---|
| A | [ ] SUPPLEMENTAL SHEET *(Complete Part B. Items 1 and 2 only.)* | | [X] LETTER OF EVALUATION *(Complete Part B. Items 1 thru 4.)* | | |
| B | 1. FROM 10 Mar 80 | 2. THRU 28 May 80 | 3. REPORT IS | [X] MANDATORY | [ ] OPTIONAL |
| | 4. REASON FOR REPORT | X | CRO 60 OR MORE DAYS SUPERVISION | | SPECIAL OR ADDITIONAL DUTY |
| | | | CRO LESS THAN 60 DAYS SUPERVISION | | PIPELINE STUDENT |
| | | | GEOGRAPHICAL SEPARATION/TDY | | OTHER - EXPLAIN IN SECTION III |

**III. COMMENTS**

The AF Form 77 should be typed. If no typewriter is available, entries must be printed or legibly written in reproducible ink (black or dark blue only). In all cases, confine comments to the space provided on the form. Sign the original in reproducible ink (black or dark blue only); if additional copies are required the remaining copies may be signed, initialed, or stamped "SIGNED." When rendering an LOE, use the heading "FACTS and SPECIFIC ACHIEVEMENTS" followed by appropriate comments. This heading is mandatory on all LOEs. Omit other headings entirely if not followed by comments. Headings must be entered in the order shown in figure 3-3.

**IV. EVALUATOR IDENTIFICATION DATA**

| | | |
|---|---|---|
| 1. NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND, LOCATION<br>ROGER S. SALISBURY, Major, USAF<br>35th Cmbt Spt Gp (TAC)<br>George AFB CA 92392 | 2. DUTY TITLE Chief, CBPO | 3. DATE 28 May 80 |
| | 4. SSAN 000-00-0000 | 5. SIGNATURE Roger S. Salisbury |

AF FORM MAY 79 77 REPLACES AF FORM 77A, NOV 74, WHICH IS OBSOLETE. SUPPLEMENTAL EV ... ION SHEET

Figure 3-6. AF Form 77.

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2. How do you prepare an APR on an airman if no one is available to type it?

You are writing an APR on an airman and you make a mistake on an entry in section III. State how you correct this entry.

When writing the comments on an APR, you misspell a word that can be corrected without changing the meaning of the sentence. What action is required in this case?

**056. State how to use job performance appraisals for civilian personnel.**

The job performance appraisal system (JPAS) establishes performance standards and identification of critical and noncritical job performance elements used as a basis for personnel decisions to reward, assign, promote train, retrain or remove employees. Personnel management uses the performance appraisal as an evaluation device for all civilian employees. The appraisal procedures are uniform throughout the Air Force. But each supervisor must prepare a work plan that describes job requirements and performance standards expected for each employee. As a supervisor of civilian employees, you must review each of your worker's performance periodically.

**Performance Appraisals for Civilian Personnel.** You should be familiar with AFR 40–452, *Performance Appraisal System*. This regulation explains the civilian appraisal system and establishes the supervisor's responsibility to appraise civilian workers.

A performance appraisal is due for each civilian employee annually unless circumstances require a change to the appraisal period. As the rating supervisor, you must review the mission of your unit to determine if the job descriptions of each employee accurately describe the duties and responsibilities required to complete the mission. You then prepare an AF Form 1282, Job Performance Appraisal, for each civilian employee under your supervision.

*Preparing AF Form 1282*. The AF Form 1282 is the document used to record an employee's work plan and overall performance rating. You should read the instructions that give you general information about the work plan and rating sections on page 1 of the form. Then, complete the employee identification part of the form as specified on page 1. Next, you must type in the names, grades, and duty titles of the supervisor and reviewing official in the work plan authentication section. When you complete the work plan, you, the supervisor, reviewing official, and the employee should sign and date this section. Now, let's discuss other parts of the AF Form 1282.

*a*. Part I—work plan job performance elements. Enter the employee's job performance elements on page 2, Part I. The elements are requirments of duty performance and are normally taken from the employee's job description. They are further broken down into critical and noncritical.

Critical elements are job performance elements that management considers very important. Failure of the critical elements may require remedial action and denial of merit pay or within-grade increase, and may be the basis for removing, reassigning, or demotion of an employee. Noncritical elements are job performance elements used to determine the overall performance level. Performance below the minimum standard requires counseling the employee.

*b*. Part II—work plan and performance standards. This is a written statement of the quantity and quality of performance expected for the job element listed on page 2 of the AF Form 1282. There may be more than one standard for a single job performance element.

*c*. Part III—performance substantiation and overall performance rating. When the employee's rating is made, you must write supporting evidence for the elements evaluations on page 4, part III of the form. This means that you need to compare the employee's job standard with the actual performance of the employee throughout the year. This is where you enter your comments on all job performance elements listed on page 2 of AF Form 1282. Then assign an overall performance rating.

Performance appraisals were designed to be used as the first step in a total management system to identify and correct work performance problems. They help you plan OJT classes and request formal training when needed. They can also recognize and reward quality performance of outstanding civilian employees.

Wouldn't you want your supervisor to tell you what you aren't doing right so that you can correct it? Then you should never let the ratings on the appraisal be a surprise to *your* employees. You must take the time with your employees and discuss their performance with them. Every few months you should check and revise job performance elements and performance standards that no longer apply.

**Exercises (056):**

1. What type of device is the job performance appraisal?

2. How often are job performance appraisals due?

3. What will determine the duties and responsibilities of each civilian employee job description?

4. What are the two classes of job performance elements?

5. Failure of what class of job performance element requires remedial action?

6. What part of the AF Form 1282 will the supervisor enter an overall performance rating?

## 3-2. Training

The Air Force OJT program is a systematic, reportable application of the craftsman-apprentice relationship, by which the trainee acquires job skill and knowledge and becomes a skilled worker. Throughout the Air Force, OJT is an essential and significant part of the integrated training program. It is a part of every unit's mission and requires the vigorous support of supervisors at all levels.

OJT is the primary method for training airmen to the skilled (5) level, and it is one of the two methods (OJT and resident school) for training them to the semiskilled (3) level. Advanced (7) level training may be accomplished entirely through OJT or through a combination of formal and on-the-job training.

As a trainer, you must be able to explain OJT program objectives in terms of both the Air Force mission and the position of the trainee. To do this, you must have a good understanding of the airman career program, particularly as it applies to your career field.

### 057. Explain the Air Force integrated training program in terms of personnel, types of training requirements, and responsibilities.

**Integrated Training Program.** The Air Force on-the-job training (OJT) program provides training for Air Force enlisted personnel to qualify them in the knowledge and job proficiency required to perform duty in an Air Force specialty (AFS). All Air Force organizations with assigned enlisted personnel conduct OJT.

*Relationship between formal training and OJT.* Air Force airmen technical training requirements are met by an integrated program involving all Air Force commands and some schools of the Army, Navy, and other Government agencies. The Air Force conducts a continuous and aggressive OJT program as a part of its integrated training program. Headquarters USAF, Director of Personnel Programs establishes training policies to ensure that OJT is integrated with all other elements of training. The Air Force Manpower and Personnel Center (AFMPC), Training Management Division provides overall management for the OJT Program. The Air Force recognizes that there are three specific requirements that airmen must satisfy to qualify for skill level upgrading. These requirements are career knowledge, job proficiency, and job experience. The Air Force dual channel OJT program is designed to satisfy the requirements for career knowledge and job proficiency. The requirement for job experience is satisfied when airmen satisfactorily perform duty in their AFS for the minimum time specified in AFR 35—1, *Military Personnel Classification Policy (Officers, Warrant Officers, Airmen).*

*Formal training.* Formal Air Force training includes training conducted both in approved courses and on the job. Air Training Command (ATC), in coordination with major commands (MAJCOMs), determines the requirements for, prepares, evaluates, and revises specialty training standards (STSs). These standards specify the amount of knowledge and skill required for training. They are the primary control documents for formal resident courses, career development courses (CDCs), OJT job proficiency guides, (JPGs), and specialty knowledge tests (SKTs). CDCs are used in conjunction with job proficiency training in the Air Force Dual-Channel OJT Program and as the primary reference for most SKT questions. The Extension Course Institute (ECI) publishes and administers CDCs.

Each MAJCOM must plan, conduct, and evaluate OJT according to regulation through practical application of the Dual-Channel OJT Program. In this text, references to the Dual-Channel OJT Program apply to that part of the Air Force training that conforms to the definition of OJT.

*On-The-Job Training.* On-the-job training is a planned training program designed to qualify airmen, through self-study and supervised instruction, to perform in a given AFS while actually working in a duty assignment of their AFS.

**Exercises (057):**

1. Which Air Force organizations must conduct on-the-job training?

2. Why must an organization conduct OJT?

3. What organizations are involved in meeting airman technical training requirements?

4. What organization insures that OJT is integrated with all other elements of training?

5. In addition to career knowledge training, what other requirements must an airman satisfy to qualify for upgrading?

6. The STS is the primary control document for what training and tests?

7. Is OJT formal or informal training?

8. What is the responsibility of each major command toward the OJT program?

9. Define "OJT."

10. What is formal Air Force training?

**058. Describe the Dual-Channel OJT Program in terms of purpose, where and how it is conducted, and the role of the JPG.**

**Dual-Channel OJT.** The Dual-Channel OJT Program is based The Dual Channel OJT Program is based upon the idea that there is, in career development, certain knowledge that airmen must gain if they are to move forward in the career field and if they are to have the ability needed to move quickly from one kind of equipment or system to another, or from one job to another. This knowledge is kin to, and concerned with, basic principles and theories. It is also involved with developing job proficiency by applying career area knowledge and by performing tasks related to a specific job assignment.

Dual-channel OJT is a systematic, reportable application of self-study and the craftsman-apprentice principle. Trainees acquire AFS knowledge by enrolling in and studying CDCs, when available, or by studying the study/technical references listed in the appropriate STS if CDCs are not available. Trainees gain job proficiency while performing on the job under supervision. This combination enables the airmen, upon reassignment, to perform, after a period of qualification training, the duties to which they are assigned in another unit.

OJT is conducted in the actual work situation by designated personnel who are working in support of the unit mission. Even though the responsibility for conducting OJT is delegated to specific individuals, the overall OJT program is of concern to every person assigned to the unit.

OJT is an integral part of every unit's mission. It requires vigorous support of commanders and supervisors at all levels. To be effective, an OJT program requires comprehensive planning, careful scheduling, timely implementation, capable direction, skillful application, and searching evaluation. As stated earlier, there are two distinct parts of the Dual-Channel OJT Program—knowledge and job proficiency development—which must be interpreted as career knowledge training and job proficiency training.

Career knowledge training is administered under one of two methods, depending on the availability of CDCs. Use of the CDC is mandatory if CDCs are available. If a CDC is not available, use the STS study/technical references (S/TRs) to satisfy the knowledge requirement for award of the appropriate skill-level AFSC. If neither a CDC nor STS is available, command and local JPGs will outline specific knowledge requirements.

The job knowledge training part of the Dual-Channel OJT Program is graphically depicted in Figure 3-7. The following paragraphs describe the other half of the Dual-Channel OJT Program—the job proficiency training phase, also shown in Figure 3-7.

Immediate supervisors are responsible for the development, maintenance, and effective use of JPGs. JPGs are used to assist in developing the trainee's job proficiency. The JPG provides airmen with specific reference to an authoritative publication for each task in their current duty assignment. As ATC revises STSs, specific references— including chapter and section number of TOs and other references are added. This procedure eliminates a great deal of unnecessary reading.

Air Force jobs require various combinations and degrees of skill and knowledge. Some are highly complex and require lengthy training periods; others are less complex and require correspondingly less training. Most of the training for the less complex jobs is conducted at unit level through OJT programs which include self-study and job proficiency training. For the more complex jobs, the ratio of the knowledge-to-skill requirements of the particular job determines the kind of training for an individual selected for that job.

For some complex AFSs, primary consideration must be given to the knowledge requirements. Since knowledge is most readily acquired in the classroom, it follows that most airmen who are selected for training into such jobs receive their initial training in formal technical schools.

In other types of complex jobs, the greater emphasis must be placed on the requirements for skill; therefore, supervised training on the job is often the most practical way of producing competent personnel. A 3- or 5-skill-level CDC provides the necessary career area knowledge for the OJT trainee.

After airmen have recieved appropriate initial job knowledge training, either in a formal school or on the job, the airmen still have to become thoroughly proficient in a duty position of the specialty for which they were trained. A formal school situation obviously does not lend itself to proficiency training. For individuals to become thoroughly skilled in the duty position, they must become semiskilled as a result of either a formal school or on-the-job training. They must receive additional training on the job to become fully skilled workers.

Since the entire OJT program hinges upon the learn-by-doing and self-study concepts, it follows that the part of the Dual-Channel OJT Program called job proficiency training is normally conducted within the unit to which the airman is assigned for duty. The responsibility for conducting the job proficiency phase of OJT is inherent in the job of each person, including civilians, who supervise the work of airmen. The responsibility for the career knowledge training part of OJT through self-study courses rests with the individual concerned. This training is monitored by the

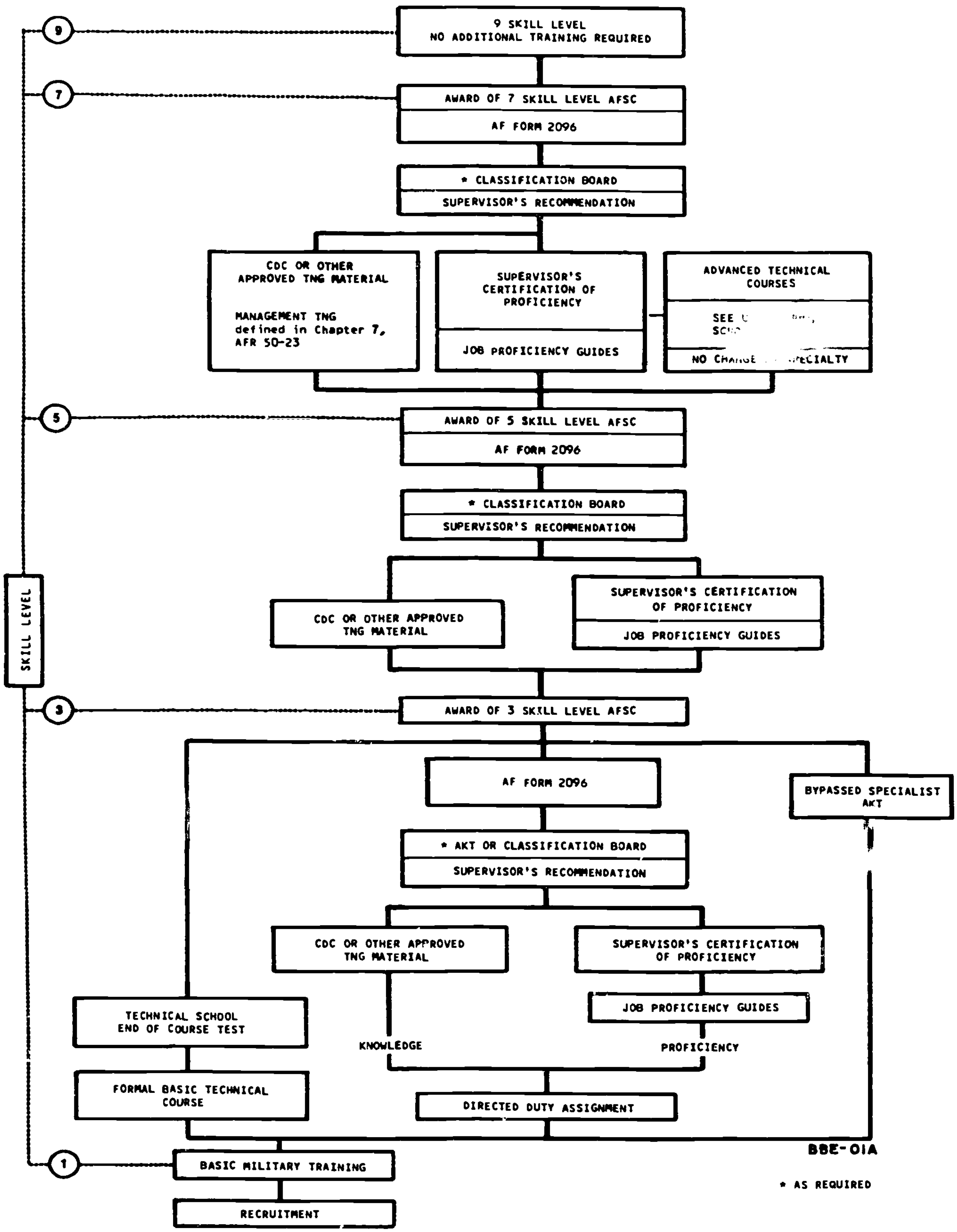


Figure 3–7. Skill progression.

100

airman's immediate supervisor and the squadron OJT manager.

Job proficiency training implies practical application. It is that part of formal OJT which teaches skill. It places trainees in operational situations where they are assigned certain tasks which are part of their duty assignment. As trainees acquire skills in the simpler tasks, they are assigned others which are progressively more complex. In this way, trainees are constantly broadening their skills and knowledge, ultimately to inciude all elements of the job.

Learning in a job proficiency situation results from the close association between the trainee and the trainer. Understand, however, that this coach-pupil method of training does not preclude short periods of informational group instruction on job proficiency training elements.

**Exercises (058):**

1. What is the purpose of the dual-channel OJT program?

2. Where is on-the-job training conducted?

3. By what method(s) is OJT conducted?

4. What is OJT an integral part of?

5. How is the JPG used in OJT?

6. What determines the tasks an airman performs in OJT?

7. Who is responsible for identifying tasks an airman must perform during OJT?

8. If airmen need a specific reference on how to perform a task, where can they find it?

**059. Define the different types of training and relate them to OJT.**

OJT and UGT. On-the-job training is an all-inclusive term which describes the training received by an airman while he or she is performing in a duty assignment of the AFS. Training for the purpose of upgrading an airman's skill level in his or her AFSC is referred to as upgrade training (UGT). Training administered for the purpose of increasing knowledge and skill in an awarded AFSC, but not resulting in award c an AFSC, is referred to as qualification training.

**Qualification Training.** A program of qualification training designed to develop more knowledge and skill within an airman's assigned position is a basic part of the OJT program, but it does not result in the award of an AFSC. Qualification training does not require the use of special orders; AF Form 2095, Assignment/Personnel Action; AF Form 2096, Classification/On-The-Job Training Action; c but it does require entries on the JPG. Qualification training provides additional training for airmen who have already been upgraded in their specialties. It provides a practical application of the commander's awareness of the need for gearing the capabilities of the unit to changing Air Force concepts, requirements, equipment, and unit missions as well as recognizing that there is always a need for increased skill and knowledge within the broad confines of each skill level. Qualification training becomes critical when the commander is faced with the need for increasing the quality or amount of production, indoctrinating personnel in new techniques or procedures, or qualifying technicians to maintain new equipment.

Proper application of qualification training provides additional valuable experiences for all airmen who have been upgraded in their specialties to the 5- or 7-skill level.

**Retraining Programs.** Retraining through OJT is defined in AFR 39-4, *Airman Retraining Program*. It is designed to qualify an airman for award of an AFS or AFS shredout not in the normal progression pattern of a currently awarded AFS.

**Lateral Training.** Lateral training is accomplished in an AFS where the designated input is from another AFS. Lateral training, a planned part of the normal progression for certain AFSs, is shown in the career field charts of AFR 39-1, *Airman Classification Regulation*. Lateral Training may be given either through formal courses conducted by ATC or through OJT programs conducted at the unit level. When lateral training is given on the job, it is subject to the same controls as other OJT programs.

**Exercises (059):**

1. Define the following types of training:
   a. Upgrade training.

   b. Qualification training.

   c. Retraining.

2. How is qualification training conducted?

3. Why is there a need for qualification training?

4. In retraining through OJT, must an airman complete career knowledge training?

5. Explain your answer to item number 4.

6. If an airman is trained to the required proficiency level for every task listed in his JPG, does he need qualification training? Explain your answer.

7. What is the controlling publication used for:
   a. Lateral training?

   b. Retraining?

**060. Associate responsibilities for the OJT program with the person to which the responsibility is assigned.**

**Immediate Supervisor.** Responsibility for conducting OJT is inherent in the position of all supervisors. Since the supervisor (military or civilian) has daily contact with all the personnel assigned to the unit, the supervisor occupies a key position in the OJT program. In smaller sections, the immediate supervisor may also be the trainer. In any case, the title, immediate supervisor, is applicable to that person who maintains OJT records and forms and is responsible for those duties and responsibilities.

**Selection of OJT Trainers.** Ideally, the OJT trainer is the trainee's immediate supervisor. However, for various reasons this may be difficult to arrange in some organizations. As a result, trainers may be appointed to provide training for individuals or small groups of trainees. Appoint trainers who have broad fundamental knowledge and technical know-how, as well as the ability to get along with people and inspire the confidence of the trainees. The trainer is not to be thought of as an individual assigned to full-time instructional duty, but rather a skilled worker who is assigned to a production job.

**Relationship of Trainer to Trainee.** The on-the-job trainee needs motivation. Motivation stems from a felt need. The trainees should feel the need for OJT when the immediate supervisor accomplishes the requirements of AF Form 623, Section II, On-The-Job Training Record. The trainees must understand the need, the objectives, and the procedures of OJT, as well as their responsibilities to accept and perform training assignments to the best of their abilities. The supervisor or trainer has to adapt orientation procedures to each situation to make clear to the trainees their responsibilities as presented in Chapter 4 of AFR 50—23.

**Exercises (060):**

1. Match the responsibility for the OJT program in column B with the assigned person in column A by writing the appropriate letter in the blank. (All persons have three or more responsibilities listed.)

*Column A*

_____ (1) Immediate supervisor.
_____ (2) OJT trainer.
_____ (3) OJT trainee.

*Column B*

a. Maintains all issued training materials in good condition for future use.
b. Maintains AF Form 623 for assigned airmen.
c. Instructs trainee on actual equipment.
d. When reassigned, obtains and delivers appropriate CDC materials to new unit OJT manager.
e. Teaches theory and background information when required.
f. Indoctrinates trainers and trainees on objectives of the OJT program.
g. Motivates and evaluates assigned training.
h. Certifies completion of job proficiency training.
i. Accepts and performs all training requirements and assignments in an efficient manner.
j. Using the duty section Master Job Proficiency Guide, develops the JPG as a basic document for training, based on the airman's duty position.

**061. Identify selected training principles and methods, and compare OJT techniques with formal training techniques.**

**Training Principles.** Certain basic and easily understood principles apply to all training situations. Trainers should understand and apply the principles outlined below. These principles will help trainers to improve their skill in instructing.

*a.* Go from the known to the unknown. Find out what the trainees know about the [illegible] and build from there. Relate the new material to previously learned subjects. Give trainees a complete briefing on the overall program and tell them where they fit into it. Acquaint them with the goal. Make sure the part they play in the organization is understood and make them aware that they are vital members of the team.

*b.* Go from the easy to the difficult. Always begin with the simple parts of a job. The knowledge that they are able to perform parts of the job after a practice period gives the trainees confidence and inspiration to learn the whole job.

*c.* Emphasize accuracy and understanding rather than speed, while the trainee is learning.

*d.* Emphasize safety at all times.

*e*. Clearly define the limits of the training objective and let the trainees know what is expected.

*f*. Present new material in short units that can be finished in one training session. Short, related training units are not so likely to confuse the trainees.

*g*. Be sure the trainees see the job as a whole. Fit all the short steps into the whole operation or objective.

*h*. Always remember that the trainees learn by doing. Put them to work as soon as they understand what they are to do. Give them plenty of practice.

*i*. Allow trainees to develop. They do the learning; you guide and help. Be careful not to dominate, but do not relax your supervision to a point that would allow the trainees to harm themselves, others, or damage equipment.

*j*. Any training procedure must make sense to the trainees. If it doesn't, change or discard it.

[illegible] Re[illegible]gnize the trainees' work. Let them know how [illegible]ng.

[illegible] Never try to bluff. Never resort to sarcasm or ridicule.

**Training Methods.** An OJT trainer must assume trainer responsibility, in addition to other duties; the OJT trainer function is not considered a full time duty. Supervisors may sometimes be required to perform as trainers. OJT trainers are expected to use effective training methods and techniques. This requirement and responsibility is contained in the specialty description of all skilled and advanced level AFSs. It follows that those who are selected as trainers must learn to perform efficiently, using methods that result in an effective OJT program. Job instruction generally involves four methods of imparting new knowledge or manual skills.

*The lecture*. The lecture is useful for imparting information. Its effectiveness is increased when it is combined with one or more of the other instructional methods.

*The discussion*. The discussion is a valuable training method because it promotes a two-way exchange of ideas during group instruction, when the objective is to provide background information or procedures that are of common interest to the entire group. Questioning is very useful when employing the discussion method to inform the trainees, as well as to check their grasp of the instruction. To help the trainee think through the logical steps of a new job task, phrase your questions so that they can't be answered with a straight yes or no. Use questions that begin with such words as what, [illegible]here, when, why, and how. Questioning can be [illegible] effe[illegible]vely with all other instructional methods, as w[illegible] with [illegible] [illegible]n method.

[illegible] demonstration or showing is [illegible] the training objective is the development of new manual skills. It is particularly useful in presenting the various steps of a very long operation that must be performed without stopping. The trainees are taught a part of the job, with the trainer doing the rest. After learning one step of the total job, the second step is taught, with the trainer again completing the operation.

*The performance*. The performance is by far the most effective method to use in OJT. Trainees truly learn by doing under the watchful eye of a trainer while performing in a productive capacity. It follows that airmen on OJT should immediately be given simple jobs to do, such as cleaning or sorting parts, counting pieces, sorting papers, learning names of parts, or checking supplies. It is most practical to assign such airmen to assist others who are producing. After airmen have received training on some particular task or phase of work, they are able to do it with the desired proficiency. They should then be rotated to another task. With a progressive rotation plan, trainees grow in skill and knowledge until they are able to accomplish effectively the requirements of the duty position.

**Training Techniques.** Supervisors must make sure that trainers develop a set of techniques similar to the five steps which follow so that all OJT can be effectively conducted.

*Step 1*. Prepare the training situation.

*a*. Make sure that the tools and equipment are on hand and in working order.

*b*. See that the shop or room is available and that it is properly heated, lighted, and ventilated.

*c*. See that training aids planned for use are available and in good working order.

*Step 2*. Prepare the trainees to receive job instruction.

*a*. Put them at ease. This helps build confidence. The supervisor's training efforts are likely to be in vain if trainees are nervous or ill at ease.

*b*. Find out what they already know about the job. Don't tell them things that they already know. Start where their knowledge ends.

*c*. Gain their interest. Explain the job or operation at hand and relate that job to the work of the whole unit. This helps them realize the importance of the job.

*d*. When demonstrating a job, make sure the trainees observe from the proper position. Don't have them look backwards or from an angle other than the one from which they will work.

*Step 3*. Present the operation.

*a*. Tell, show, illustrate, and then question. Once understanding is achieved, have the trainees perform the task.

*b*. Give only a few instructions at one time. Understanding is gained more quickly if ideas are presented gradually.

*c*. Make the key points clear. These make or break the operation; to a large extent, they determine the ultimate success or failure of the training.

*d*. Use availab[illegible] [illegible]raining aids when they help to put the [illegible] [illegible]ross. [illegible] [illegible]se ther[illegible] just to fill in time. Be[illegible]ore using [illegible]y training aid, be sure that it applies directly to the subject and that it works.

*e*. Be patient; remember that haste makes waste. Work for accuracy first, speed later.

*f*. Repeat the job and explanation, if necessary.

*Step 4*. Try-out performance.

*a*. Have the trainees do the job under observation. Then repeat the job and have them explain what they are doing, and why. Some people don't realize the importance of motions they are observing and repeating. The trainees must understand not only what, but why.

*b*. Have the trainees explain the key points. Correct any errors, but do not correct in a way which will make them feel that you are not satisfied with their progress.

*c*. Continue to have the trainees perform and explain until you know that they understand what they are doing.

*Step 5*. Followup.

*a*. Put the trainees on their own so they will get the feel of the job by doing it. Tell them who they should go to for help, and make sure the designated individuals understand their responsibility.

*b*. Check trainees' work frequently—perhaps every few minutes at the start, then every few hours. Be on the lookout for incorrect or unnecessary moves, but don't make an issue over them. Expect a few mistakes; if there are none, congratulate the trainees for a job well done.

*c*. Taper off the coaching until the trainees are able to work under normal supervision. Be sure that the trainees are adhering to the approved safety practices. Safety is one of every supervisor's most important responsibilities. Make it clear, both by instruction and attitude, that, strictly speaking, accidents don't just happen—they are provoked. The cause of an accident may not always be readily apparent, but it can usually be found. Common causes include lack of skill, poor work habits, poor attitudes, and/or faulty instructions. If you discover that trainees are having more than their share of accidents, and if you have eliminated faulty instruction as a possible cause, report the fact to your supervisor for action.

**Exercises (061):**

1. Match the principle in column B with the definitions or situations in column A by entering the proper letter in the space provided.

*Column A*

_____ (1) The trainer patiently explains a performance step to a trainee for the third time.

_____ (2) A trainer stops a trainee from turning on a switch that should be OFF during maintenance.

_____ (3) The trainer tells trainee what the end product will be.

_____ (4) A trainer starts the instruction on how to do a simple task.

_____ (5) The trainer explains where the [illegible]nee fits in the organi- [illegible]

_____ [illegible] [illegible]es are warned of high [illegible]ise levels and shown how [illegible]ert earplugs.

_____ (7) Let trainee do task with only an occasional check after you know trainee can do it.

_____ (8) Trainer praises good work habits used by trainee.

_____ (9) Let trainee do task as soon as you know it is understood.

_____ (10) The trainer compares operation of a centrifugal pump to a rotary lawn mower.

_____ (11) Trainee can do a complete operation at end of each training session.

_____ (12) After trainer explains an operation, trainee is asked to explain it.

_____ (13) Trainer explains what trainee should be able to do at end of training period.

_____ (14) Have trainee do task several times while trainer watches.

*Column B*

a. Go from the known to the unknown.
b. Go from the easy to the difficult.
c. Emphasize accuracy and understanding.
d. Emphasize safety.
e. Define limits of the training objective.
f. Trainer learns by doing.
g. Recognize the trainee's work.
h. Present new material in short units
i. Allo[illegible] [illegible] develop.
j. Let trainee see job as a whole.

2. The lecture method is useful for teaching information, but why is the performance method of instruction the most effective to use in OJT?

3. Why should a combination of teaching methods probably be useful with new trainees?

4. How do the training techniques compare with the techniques used in a formal training course? (Compare OJT trainer activities to classroom instructor activities—step by step.)

**062. Identify the purpose of, and the responsibilities for, the task breakdown, and give selected techniques for "breaking down" a task.**

As the instructor breaks down the objectives into segments for the lesson plan, so should the trainer break down tasks into teachable segments.

**Task Breakdowns.** Specialty training standards break down an AFS into various individual tasks and knowledges. These tasks and knowledges are required for each specialty within the ladder to indicate the extent of knowledge or degree of proficiency required for each skill level. However, many of the individual tasks and items are in [illegible]emselves quite complex. The OJT trainer must break these [illegible] a logical, systematic sequence of parts and [illegible]h each part as a complete unit. These written [illegible]akdowns of complex tasks or operations are known simply as task breakdowns.

*Purpose of the task breakdown*. Many OJT trainers may think they know a task when they really don't. Others may know the task so well that they neglect to clarify a point which is simple to them but confusing to the trainee. Still others may know the task so well that they do not plan how to teach it to another person.

For some tasks, the breakdown may be as simple as saying to the trainee, "Do this first, this next, and then do that." However, many Air Force jobs are extremely complex. Complete performance of such jobs is overwhelming to the young and inexperienced airman.

The purpose of the task breakdown is to divide the big job into easy, progressive, and teachable units. This makes it possible for the airman to learn the job in small doses, one step at a time.

The degree of which a task must be broken down depends on the past experience and learning capability of the trainee. The trainer must determine when the task is broken down far enough to be easily taught and readily understood.

*Format of the task breakdown.* [illegible] ment device, the task breakdown consists [illegible] ally of two columns. One is titled "Important steps" and the other is titled "Key Points."

(1) Important steps. The steps are logical segments of the operation which advance the work. These breakdowns are not intended to be hairsplitting; rather, they are to be simple, common sense reminders of what is really important in doing a task.

(2) Key Points. Knowing what the key points are and how to pick them out quickly and easily is an important part of job instruction. They are:

- Hazards which may cause injury to personnel or damage to tools and equipment.
- Things which make or break the task.
- Things which make the work easier—knack, trick, feel, and special timing.

*Preparation of the task breakdown.* There are several procedures by which trainers may prepare task breakdowns. Their own experience and the type of task to be performed determine which procedure to follow.

Some tasks may be so well understood that they can be analyzed and divided into simple, logical steps, just by thinking through the various stages of the operation. Others may be too complex to break down without going through the entire operation and making notes on the performance of each part.

Sometimes trainers may have to break down a task in which they've had little personal experience. If so, they should carefully watch the motions and steps used by someone more expert in the task.

In each case the objective is to find how the trainer can best help the trainee to perform each operation safely, easily, correctly, and quickly. This involves the knacks, tricks of the trade, special timing, key points, and special information on what to look for, where to look, how to feel, and what to listen for, in each operation.

Task breakdown sheets are not necessarily intended to be given to the trainee. They are for the trainer's use in clarifying and organizing their own thinking about the task. For this reason, it is not necessary to formalize them.

All tasks are identified in a general manner in JPGs. However, the task breakdown should be prepared personally by the on-the-job trainer. As with most other operations, task breakdowns can be made easily and quickly after a little practice.

Supervisors should arrange for group instructions, discussions, practice sessions, and critiques with trainers, to ensure proper preparation of task breakdowns.

**Exercises (062):**

1. Why must some tasks be broken down before you attempt to teach them?

2. State the purpose of the task breakdown.

3. The degree to which a task must be broken down depends upon what factors?

4. Give the two column headings that should be used in preparing a task breakdown.

5. What should be your objective in preparing a task breakdown?

6. Who is responsible for preparing the task breakdown?

7. Who must insure the proper preparation of a task breakdown?

**063. Cite the requirements for a training capability and the actions to take if the training capability is questionable or nonexistent.**

**Training Capability.** When planning your OJT program, find out if your unit has a training capability. You may assume that your unit or section has the capability to accomplish the prescribed OJT. But it is possible that local situations or temporary conditions may make realistic on-the-job training impractical or impossible. We will look at the question of training capability from three view points: when a training capability exists, when a training capability is questionable, and when a training capability does not exist.

*When a training capability exists.* In general, for a training capability to exist, there must be a CDC for the AFSC and/or the Specialty Training Standard/Study References (STS/SRs) and a person capable of administering job proficiency training. There are many misconceptions about the subject of training capability. The most prevalent one is the belief that the trainer must possess the same AFSC at the same or higher skill level in which the training is desired. Another belief is that to "certify" job proficiency, the person doing the certifying must be technically qualified to perform the function being

| REQUEST FOR ISSUE OR TURN-IN | I | ISSUE / TURN-IN | SHEET NO. 1 | NO. OF SHEETS | 5. DOCUMENT NUMBER |
|---|---|---|---|---|---|
| 1. FROM: | 6. DATE MATERIAL REQUIRED | | | | 7. FAD/UJC OR PRIORITY |
| 2. TO: | 8. DOCUMENT NUMBER | | | | 9. POSTED — DATE / BY — DATE / BY |
| 3. ACCOUNTING AND FUNDING DATA | | | | | |
| 4. END ITEM IDENTIFICATION — A. NAME AND MANUFACTURER | B. MODEL | C. SERIAL NUMBER | D. PUBLICATION | | |

| ITEM NO. A | STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIAL AND OR SERVICES B | CODE C | UNIT OF ISSUE D | QUANTITY E | SUPPLY ACTION F | UNIT PRICE G | TOTAL COST H |
|---|---|---|---|---|---|---|---|
| 1. | XXXX-XX-XXX-XXXX, 5/8 auger bits | | ea | 6 | | .55 | $3.30 |
| 2. | XXXX-XX-XXX-XXXX, leather work gloves | | pr | 6 | | .45 | $2.70 |

/////////////////////////////////////// Last Item ///////////////////////////////////////

Justification: These items will be used to replace like items that have worn out due to fair wear and tear.

| FIA CODE | BUDGET CODE | SHEET TOTAL |
|---|---|---|
| *ISSUE: I—Initial; R—Recurring; N—Non-Recurring | TURN-IN: U—Unserviceable; S—Serviceable | GRAND TOTAL |

| 10. ISSUE OR TURN-IN OF QUANTITIES IN "QUANTITY" COLUMN IS REQUESTED | DATE | BY | 11. RECEIVED QUANTITIES IN "SUPPLY ACTION" COLUMN | DATE | BY |
|---|---|---|---|---|---|

AF FORM OCT 71 1801 PREVIOUS EDITION WILL BE USED

Figure 2-15. AF Form 1801.

| Issued To Name<br>TYPED OR PRINTED NAME, GRADE AND ORGANIZATION | Issuers Supervisor<br>TO: *(Responsible Officer)* | ORG. ACCT. NO. | DATE ITEM(S) TO BE RETURNED |
|---|---|---|---|

| STOCK NO. | DESCRIPTION | UNIT | QUANTITY ISSUED | COST |
|---|---|---|---|---|
| XXX-XX-XXX | 3/4 inch CONDUIT BENDER | 1 | EA | $16.00 |
| | LAST ITEM | | | |
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I ACKNOWLEDGE RECEIPT AND RESPONSIBILITY FOR ITEM(S) SHOWN IN "QUANTITY ISSUED" COLUMN, WHICH WILL BE RETURNED ON DATE SPECIFIED ABOVE.

| DATE | SIGNATURE | DUTY PHONE | ISSUED BY |
|---|---|---|---|
| | PERSON ISSUED TO | | YOUR NAME |

AF FORM SEP 70 1297 PREVIOUS EDITIONS WILL BE USED **TEMPORARY ISSUE RECEIPT** c48—15—83541-1 GPO



Figure 2-16. AF Form 1297.

If you do find equipment or materials that are substandard or defective, it is your responsibility to submit a materiel deficiency report. Refer to TO 00–35D–54, *USAF Materiel Deficiency Reporting System,* and AFR 66–30, *Product Improvement Program for Operational Equipment,* for guidelines to help you complete the report.

All personnel are responsible for submitting reports on substandard or defective materials and equipment. Such reports will improve the quality of materials and equipment used by USAF organizations.

**Exercises (041):**

1. Who is responsible for submitting a materiel deficiency report on an unsatisfactory item?

2. What references can be used for reporting materiel deficiencies?

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# Supervision and Training

YOUR SPECIALTY description tells you that one of your responsibilities is to supervise electrician personnel. If you examine that description, you are sure to get at least one impression—that you need to know more than just how to install and maintain electrical systems. You need to know how to get along with people and how to keep them working effectively. You also need to know your job well and how to train the people who work for you to do a better job. That is what this chapter is all about, supervision and training.

## 3-1. Supervision

A prominent writer on management topics once wrote that: Supervision = job proficiency + leadership + management. But formulas are ordinarily summarizing devices and often oversimplify. In addition to the three traits, job proficiency, leadership, and management, a supervisor must be able to orient newly assigned personnel, establish priorities, schedule and make work assignments, and rate personnel. You can see from this list that a supervisor must be a person of "many hats." Supervisors must be able to change from one role to another at a moment's notice. Let's review some of the traits that a supervisor must possess and some of the jobs that they must perform.

**042. For given situations, indicate how you could fulfill your responsibility for the mission.**

**Responsibility for the Mission.** You are responsible for many things but your primary responsibility is the mission. Your duty to your unit and to your personnel are secondary only to the mission. There will be times when the people who work for you will want to be absent from duty for various reasons. They will feel hurt if you do not let them go, but you must disregard the needs and feelings of your personnel in order to meet the needs of the mission. At such times, the esteem your people hold for you will suffer unless they have been thoroughly briefed with responsibility for the mission. You should impress this fact upon them through talks, discussions, training, and personal example. In spite of such orientations, not all of your personnel will support you in these demands. There are always some who place personal desires before duty; however, they will eventually fall in line and follow the majority if you are firm and stand by the first objective of your job—THE MISSION IS PRIMARY.

Responsibility to your superiors is another objective that you must realize. If you fail to support your superiors, you jeopardize your own efforts. Whenever you criticize your superiors and their methods, you, in turn, invite criticism by your personnel. They will simply be following your example. To avoid this, you should carry out the directives of your supervisor as if they were your own. A good leader must be a good follower. Should you disagree with a directive, present your point of view to your supervisor. If the directive still stands, carry it out to the best of your ability without excuse, alibi, or any attempt to pass the buck. When you can do this, it is an indication of maturity. It is also an indication that you are ready for even greater responsibilities.

At times, you may be directed to do something contrary to directives from higher headquarters. When this happens, do not hesitate to bring it to the attention of your supervisor. If you are still directed to carry out the original order, do so without reluctance. In such a situation, your supervisor assumes full responsibility for this action. You must understand that he or she is nearer to the top and knows more than you do about the overall mission. Responsibility to the mission is your first consideration, regardless of how disagreeable the order may seem. This does not mean that you can be directed to falsify official documents. To do so would compromise your integrity—your truthfulness. To do so is not only unlawful but also degrading. John D. Ryan, General, USAF, when Chief of Staff said, "False reporting is a clear example of a failure of integrity. Any order to compromise integrity is not a lawful order."

**Shop Supervisor Responsibilities.** The duties and responsibilities of the interior electric shop supervisor are listed below. They do not include all responsibilities but should give you an idea of the areas that you must be concerned with if you are in charge of your shop.

*a.* Supervises and directs shop activities to maximize production. Assigns work to workers.

*b.* Ensures compliance with the work schedule.

*c.* Helps the superintendent set standards of maintenance to include developing the recurring maintenance program.

*c.* Makes sure workers have tools and shop equipment necessary to do their work.

*e.* Identifies requirements for operating supplies and special levels to material control.

*f.* Reviews the bench stock list and advises material control of problems.

*g.* Enforces supply discipline by seeing that only authorized material and spare parts are on hand.

*h.* Advises material control of excess, repairable, or condemned equipment, materials, spare parts, and tools.

*i.* Trains and provides operating instructions to users of equipment and appliances.

*j*. Helps the planners estimate work orders and job orders.

*k*. Makes sure required records and reports are accurate, legible, complete, and submitted on time.

*l*. Reviews workload to determine capability to do all scheduled work orders and job orders. Reviews should be done before the weekly scheduling meeting.

*m*. Exercises direct supervision over all assigned military and civilian personnel.

*n*. Maintains control of workers through the controller.

*o*. Makes final inspections to complete work.

*p*. Identifies training needs and provides the on-the-job training to assigned workers.

*q*. Makes sure workers provide an AF Form 1255, Quality Control Evaluation, to customers on arrival at the job site.

*r*. Makes periodic job site checks.

**Exercises (042):**

1. You are the supervisor. The rewiring of a facility for a new flight simulator must be completed within 2 weeks. You are slightly behind schedule. Airman Jones and Airman Smith want 3 days off to go camping.
   a. What is your first consideration?

   b. How would you handle Airman Jones and Airman Smith?

2. Sergeant Sims requests 10 days TDY to attend the JSIIDS (Joint Service Interior Intrusion Detection Systems) course. The interior shop is 2 people short and is behind on work orders. As the supervisor, what should you do?

3. Colonel Y. Knot calls and wants you to install a light switch on the back of his house that afternoon. This project is not on your production schedule. What should you do?

4. You have two pipe threaders in your shop that do not work. What are your responsibilities in this situation?

5. Two new airmen are assigned to your shop. What are your responsibilities to these people?

**043. Define job proficiency and state the importance of job proficiency as it relates to you job as a supervisor.**

**Job Proficiency.** In order to get out the work, you must be able to do your job well as a supervisor. If you were to make a list of the qualities of a good supervisor, you certainly would have to place job proficiency somewhere near the top of the list. You must know electrical work or you will not know if your workers are doing their jobs correctly or not. A big part of your job is training your workers on the job. How can you train others if you don't know how to do the job yourself? For example, one task in your career field is to install power panels. There is a correct way to do this task. There is also a dangerous way to do it. You must know the difference.

The best electrical worker does not always make the best supervisor because there are a lot of other qualities to being a good supervisor. However, to be respected by the people who work for you, you must be proficient in 542X0 skills.

**Exercises (043):**

1. What is job proficiency as it relates to this course?

2. What would be *two* likely results if you tried to supervise a group of 54250 personnel without knowing jobs of an electrician or being able to perform related tasks?

**044. Given situations requiring good leadership traits, state what traits you can use to handle the situation in a manner that will not reduce effective mission accomplishment.**

**Leadership.** You be able to lead people in order to get the work done. Most people can be led readily, but they do not like to be driven. The old "whip-cracking" boss went out with the horse and buggy.

Intelligent people who expect to be leaders must know the traits of good leaders so that they can practice them. A list of these traits, which is by no means complete, follows:

*a*. Leaders understand their personnel as individuals in spite of their sex, schooling, experience, age, race or religion.

*b*. Leaders can, when necessary, be firm with workers without losing their temper.

*c*. Leaders are not afraid of their positions, their own boss, the directives, or any tough jobs.

*d*. Leaders are easy to approach and also easy to get away from almost any time.

*e*. Leaders are people you can't fool, though they may have the good sense to look away at the right time.

*f*. Leaders know most of the answers, but will admit it when there is one they don't know. They will, however, know where to get the right answer.

*g*. Leaders can show their people how to do a job without showing off or showing up their employees.

*h*. Leaders are predictable.

*i*. Leaders are honest, but can see through trickery.

*j*. Leaders identify with their employees and will fight for them, provided they are in the right. Even when they are wrong, the leader will support them and encourage them to be right.

*k*. Leaders get a kick out of their work and are able to project their enthusiasm.

*l*. Leaders believe that their work is important.

*m*. Leaders will listen to something important but remember an "appointment" when they hear idle talk.

*n*. Leaders give the impression of trying to work themselves out of their jobs and work their people into them.

*o*. Leaders get around but do not gossip.

*p*. Leaders talk in terms of joint activity. They like to stress the word "we" and mean it.

The traits above refer, of course, to good leaders. The statements are written in positive terms. For a moment let's take a look at the other side of the coin and see some of the qualities of poor leaders. Poor leaders have a negative influence on those they supervise. "A shop is a reflection of the leader" is a statement that has much truth in it. A good leader reflects a good shop. A poor leader reflects a poor shop. If the leaders have poor morale, like a contagious virus, they will pass it on to their employees. This type of situation is created when supervisors are critical of their jobs, their supervisors, and those they direct. In such a case, dissatisfied supervisors can't create enthusiasm for work and for self improvement for members of their teams. Such failure results in low productivity, poor quality products, and personnel wanting to leave the shop.

Good leaders try to avoid conflicts between their people and higher level orders which they must pass on. A full explanation of an order will often prevent misunderstanding. In group or private conferences, leaders explain possible sources of friction before their people get excited. They do not let someone else inform them of something unpleasant concerning their jobs. They try to discover the basic reason for the order; and in passing the information on to those under their supervision, they explain the order.

**Exercises (044):**

1. In the following situations, state what leadership traits you should use to handle the situation in the most effective manner.
   a. One of your workers comes to you with a fluorescent dimming ballast component you are unfamiliar with.

   b. Sgt Hassle has a personal problem and needs someone to talk to.

   c. Sgt Anderson, a female, just arrived in your shop and tells you she is willing to accept any challenge.

   d. You overhear that Amn N. Trouble is having marital problems.

   e. You have two very capable NCO's in your shop who want to help with some of the responsibilities.

   f. A group of your workers are sitting in the break area discussing a job. As the conversation lengthens they begin to discuss the party they went to on Saturday night.

   g. Amn Tom Maker has been goofing off on the job.

   h. The O&M chief has directed that your shop is going to have to work on Saturdays for the next 3 weeks to catch up on backlogged work.

   i. In the past, you have let people off who have worked overtime on the weekend.

   j. The commander is on Sgt Morgan's back for cutting power to the Officer's Club during an emergency.

**045. List the questions and steps necessary to orientate new workers.**

**Orienting New Personnel.** When new workers are assigned to your shop, you should introduce them to the job and to the people with whom they will be working. This orientation is one of your most important responsibilities because this is when the new workers get their first impression of you and their new assignment. Their first impression is good or bad, depending upon how well you, the supervisor, conduct the orientation. The effects of bad orientation take a long time to correct, whereas good orientation satisfies the four basic needs of people—recognition, opportunity, security, and a feeling of belonging.

When new workers report for duty, remember that the orientation can be a distinctly motivating factor, because it can convince them that they have found a good job in an interesting and important place to work. Before you begin the actual orientation, introduce yourself, then guide the conversation along personal lines:

*a*. Get their names correctly, then remember and use their names as you proceed with the interview.

*b*. Find out their marital status and (if applicable) the number, age, and sex of their children.

*c*. Ask their age.

*d*. Ask about their education and experience and their special training and talents.

*e*. Check on their hobbies and interests.

*f*. Find out about their home background. (You may have mutual interests, or someone already working in the shop may be from the same locality.)

*g*. Find out where they are living. If they are living off base, offer to help them find a car pool or satisfactory transportation to work.

*h*. For each bit of information you get from them, try to give them a little in return, not only about yourself, but about the people with whom they will work.

With this information, you will know better how to orient new workers. Tell them to ask questions when they want further clarification; then give the official part of the orientation as follows:

*a*. The functions and organizational structure of the shop.

*b*. Where their positions fit into the organizational structure, and the importance of their positions.

*c*. The supervisory chain of command and the person to whom they are directly responsible.

*d*. Duties and responsibilities in their positions and the opportunities for advancement.

*e*. The concepts of career development and their relationship to the career program.

*f*. The new duties from the specialty description and specialty training standard that they will learn to perform in their assignment.

*g*. The standard of work required.

*h*. Specific shop procedures and policies (duty hours, special details, special meetings to attend, etc.).

Finally, introduce them to the other shop personnel. As you walk around, point out items of interest(emparticularly those that specifically relate to their former job. Don't burden them with a lot of small details that they won't understand. Leave the small details for them to learn when they actually start doing the tasks. Introduce them, not only as new workers but as people of interest. Say something about their qualifications or interests. Take special pains to introduce them to the people who come from the same part of the country or who may know the same people. Then introduce and turn them over to the people who will be responsible for their training.

During the following days and weeks, as they train on the job, be sure to give them any needed assistance, let them know how they are getting along, give them credit when due, and gain their confidence. You must learn all you can about their emotional stability and their ability to solve the problems that might otherwise have a bad effect on their work.

**Exercises (045):**

1. Sgt John A. Brown has just arrived on base from another base. He is assigned to your shop and you need to orientate him. In the space provided below, make up a brief list of questions intended to get information about him and his background.

2. In the space provided, outline the official information you must tell Sgt Brown.

**046. State the procedures used to establish work priorities and work assignments.**

**Work Priorities.** There are many questions that you must ask yourself in order to analyze the work distribution, establish priorities, and schedule work in your shop. Some of these questions are as follows:

*a*. Which jobs are the most urgently needed?

*b*. Which activities take the most time?

*c*. Are there any jobs that are misdirected?

*d*. Are the jobs assigned to the correct shop?

*e*. Is your shop required to do too many unrelated tasks?

*f*. Is the work distributed evenly?

*g*. Are supplies and equipment available to accomplish the job?

If you have the answers to these questions, you will be in a position to see the relationship of these different jobs and can come to a conclusion. This is not to be interpreted to mean that you don't already know what is going on in your shop. We are not talking about job classification or Air Force specialty when we discuss work priorities and work distribution. Rather, we are talking about specific, detailed, factual information that is assembled in one place in an orderly way to help you make improvements more easily. In order to be a good supervisor you should always seek new ways to improve your organization.

Obviously, the most time should be devoted to the most important work—those operations that contribute most directly to the mission of your organization. Operations should be the right number and type to accomplish this mission. Time totals for other operations normally should reflect the relative importance of that operation. By keeping on the alert when you study your work distribution, you will find that the effort expended is repaid many times over. Also, you will be surprised at how much you can learn about how the work in your unit is done.

Only operations and tasks that are essential to the organization's mission should be accomplished. Work that duplicates work done elsewhere may be misdirected effort. Misdirected effort often shows up in the form of excessive personal time or time not accounted for. Any work being performed that does not contribute to the mission is likely to be misdirected effort.

**Work Assignment.** After you determine that the work is the right type for your shop and you have it scheduled for completion by priority, the next thing that you must do is to assign the people to do the job. There are several questions that you can ask yourself to help you make these decisions.

Are skilled workers doing considerable routine work or other tasks that do not use their skills? The supervisor and skilled workers should do a minimum amount of routine or other unskilled work. This can be a problem with willing workers as they may take on work below their skills.

Do workers have tasks that are above their skills or for which they are not trained? Workers doing work far above their skills usually will do less work, do poorer quality work, and cause more accidents than workers with proper skills. Skilled work should be concentrated in some positions and unskilled work in others, where possible.

Are willing workers assigned tasks that are unrelated to their normal work? Few people can do all types of work equally well; the assignment of unrelated tasks to workers can result in poorer work, less enthusiasm, and more fatigue. The assignment of related tasks to a worker makes training to increase the worker's skills easier. Willing workers should not be assigned or allowed to assume too many tasks just because of their willingness. Tasks should be organized in related groups and then assigned to appropriate workers.

Are many workers doing a small or unimportant task that one person could do more efficiently? If several workers are filing, answering the phone, cleaning the shop, or doing some similar task, the task may be badly performed and skills may be wasted. Also, tasks may be given to so many workers that no one is responsible for them. One person working steadily usually can accomplish a task more effectively than many workers doing a small part of the same task.

What do you think happens if the work is not evenly or fairly distributed among your workers? Obviously, everyone won't be carrying a fair share of work. Worker morale will decrease, accidents may increase, and some workers may be idle or "goofing off." Overloading or underloading workers will get poor results. Aim for a balanced workload among workers.

**Exercises (046):**

1. What type of work takes first consideration when making out the schedule?

2. What is misdirected work?

3. Who in your shop should do the lesser skilled, routine-like work?

4. What problems could result by assigning your workers jobs far above their abilities?

5. What is an advantage to insuring workers are assigned to related tasks.

6. List two advantages to assigning one worker to perform a routine task.

7. What could result if the work is not evenly or fairly distributed?

**047. Given four rules for organization in management principles and four situations, associate the rules with the situations.**

**Management Principles.** Your job calls for you to supervise maintenance, inspection, and repair activities. In order for you to do a good job of supervising these activities, you must have some knowledge of management principles. Management may be defined as the process of organizing, coordinating, and using resources to accomplish work that has been planned. There are many other definitions and there are scores of books written on management. To express a complex subject in simple terms, you could say that management is using common sense to get the job done efficiently. This whole chapter, Supervision and Training, relates to management principles. This particular objective is limited to the portion of management called organization.

**Organization.** To practice good management principles, you must be able to organize. Organization is a process of putting things in order in some kind of working system. You organize your room when you get ready for an inspection. You organize your thoughts before you give a speech. You organize your job and the jobs of your workers, and you organize the steps and processes by the tasks that are accomplished. You may do these things consciously or unconsciously, but one way or another YOU DO ORGANIZE. There are four principles or rules which can help you to organize your unit effectively.

*Rule 1*. The first rule is that each person must have only one boss. He or she should take orders from that one boss and receive directives and directions from only that boss. Have you ever been in a position where the big boss gave you orders that were different from those that your supervisor gave you? It is very confusing to say the least. An armed force will lose its effectiveness when the chain of command is broken—so will a shop. The saying that "no man can serve two masters" is as true today as it was 2000 years ago. Every person must know who their boss is and must take orders from that boss.

*Rule 2*. The second rule is that you must not try to handle too many people. There is no set number that one supervisor can handle. It depends on such factors as time, type of job, difficulty of work, and concentration of personnel. If the job is such that your employees work close together, you may be able to handle 15 to 20 people; but if the job is scattered, four or five may be enough.

*Rule 3*. The third rule of good organization is that you must be given the authority to get the job done. Nothing is harder on morale than to give supervisors a job and then tie their hands by not giving them any authority. If you give people the leadership to get a job done, you should also give them the authority to coordinate the work with other shops. You should give them the authority to get supplies and to draw the tools necessary for the job.

*Rule 4*. The fourth rule in organizing is that every person must answer for their own work. Supervisors must be responsible for their own jobs, which includes the work of their workers. They answer to their bosses for the work of their organizations. Of course, the workers in their organization must answer to them. Every person is responsible for his or her job to the next person above them.

**Exercises (047):**

1. Match the following rules for organization in management principles to the appropriate situation below by placing the letter of the rule in the space provided.

   a. Each person must have only one boss.
   b. One person should not be given too many people to supervise.
   c. Authority must be given to get the job done.
   d. Each person must answer for their own work.

____ (1) You are the supervisor of a very large interior electric shop. There are 30 people altogether with 6 assigned to the alarm crew, 10 to the minor construction crews, 4 on equipment maintenance, 5 on relamping, and 4 people working on service calls and job orders. You designate the ranking person of each crew as crew leader. You are in direct supervision of these crew leaders and they are in direct supervision of the people in their crew.

____ (2) In the crews mentioned in number (1) above, each crewmember is only responsible to the crew leader and receives instructions and directions from them only.

____ (3) Each crew leader is given the authority to carry out his or her jobs and draw the necessary supplies for the jobs.

____ (4) Each crew leader holds his or her people responsible for their work, you hold the crew leaders responsible for their crew's work, and your boss holds you responsible for your shop's work.

**048. State ways of giving directions so they are well received and understood and specify when oral and written directions should be used.**

**Directing Work.** Directing work is a vital activity required between the time you prepare for operations and the time that actual operation starts. It consists of issuing instructions to subordinates about what to do and how and when to do it. Good performance depends upon a clear understanding of what is to be done between the workers and the supervisor. This understanding is often quite hard to achieve since the directions given may mean one thing to the supervisor and something else to the worker.

*Two-way process*. When you give work directions, you must know your subordinates' capabilities and workloads. You need to consider the equipment, material, and supplies needed to do the work. If you ignore these factors, it will cause lost time and disgruntled workers. Maybe you can recall some examples of poorly planned work assignments. When you give an assignment, make sure that it is understood. If the workers do not understand, they should let you know. This interchange of information leads to better relations and a better view of the situation for both you and the workers. Thus, the directing of work should be a two-way process that results in improved performance and harmonious relations. To make sure that your directions are understood, ask the workers to repeat their instruction by telling you what they are going to do. Also, ask them if they have any questions. Use of the two-way process in directing helps you stop confusion and lost manhours, and insures that the worker's efforts go toward completing the job that needs to be done.

*Giving good directions*. Many of the directions you give come from regulations, manuals, and operating instructions. Use these controlling directives as guides when you prepare your work directions. However, there are some situations that call for decisions and directions that are not found in formal directives. In these cases, you must develop your own directions with the use of organizational objectives and good judgment as your guides. The way you give directions to workers will vary. Sometimes you must demand immediate action. In other situations, a suggestion of what is to be done is enough. For example, if you are giving directions to a newly assigned person, use the request type of direction. Later, you may need to alter the type of direction you give this same person because this person responds best to the demand or direct type of direction.

With experienced workers who are willing and cooperative, you get good results with a suggested or implied form of direction or by asking for a volunteer. With experienced workers, the demand type of direction often causes worker resentment and tense relations.

*Oral and written directions*. Directions can be expressed orally or in writing. Each method has its advantages. For example, it is foolish to give short, simple directions in writing. It is also poor supervision to give long, complicated directions orally. It is sometimes necessary to give oral directions to supplement written directions. This is true when you must explain a situation, when you wish to provide an opportunity for questions, or when you must be absolutely sure that a directive is understood.

To make sure that your instructions are clear and will not cause confusion or misunderstanding, be sure they answer the questions of "What? Why? When? Where? Who? and How?" If all of these questions are answered in your directions, the chance of misunderstanding is greatly reduced.

There are times, even when all of these questions are answered, the directions may not be understood because you assume that the worker has a full knowledge of the subject. As a result, you may use words that are too technical or too complex, you may not be specific enough, or you may include too little information. There are other times that your instructions may answer the six questions but turn out to be too long, too complicated, or not logically arranged. They may make the work seem unduly complicated, or may set up such vague guidelines that no one knows what is to be done. You must, therefore, not only be sure that all necessary information is included, but also must check the language used and how practical your directions are.

*Attitude of the directors*. It is not enough to be sure that the directions for doing a job are complete. The attitude of the individual who gives these directions is also important. For example, your supervisor may have asked for a recount of all the parts in bench stock. The supervisor may have finished the request with a remark such as, "Take care of it as quickly as you can, so that we can get on a job that is worth doing. Here's a copy of the count you made last week, if you want it."

It is not hard to picture what the attitude of anyone assigned to the preceding job is going to be. If the supervisor thinks it is a waste of time, the worker has little interest in the job and will do it carelessly. Both supervisors and workers must believe in the importance of the work they are doing if they are to do it well and enjoy doing it.

*Duty rotation*. Supervisors, while directing the operation of their units, should make it a point to rotate the duties of their people. A change of duty is often of value since it may keep workers from getting bored with what they are doing. It also gives you a chance to spread the less desirable jobs around so that one or two people do not get stuck with them. And, of course, rotation is an important part of upgrade training. It gives trainees a chance to be trained and get experience on all tasks for which they are responsible. An added benefit of rotation is that it gives you skilled persons who can do essential jobs when some of your people are gone. An example of how this works would be for you to assign one of your people to help you with the paperwork. This arrangement serves two purposes. It fulfills some of the supervisory and management training requirements for 7-level trainees and, at the same time, you are getting an assistant who can free you from spending so much time in the office.

**Exercises (048):**

1. State the reason that directions given by the supervisor do not always get carried out.

2. Specify how you can be sure that your directions have been understood.

3. Where do many of the directions used to guide your workers come from?

4. State two things you should use as guides when you must develop directions for your workers.

5. State the type of direction that is inferred in each of the following examples.
   a. "Sergeant, would you repair that hole?"
   b. "It would help if we removed this before we repair it."
   c. "Airman Jones, replace that unit."
   d. "Who is willing to stay late so we can get this job done?"
   e. "Sergeant Thomas, there seems to be a short between "C" phase and neutral."
   f. "Would you complete the entries on this form for yesterday's operation?"

6. State the conditions under which written directions should be prepared.

7. Why is it necessary to give oral directions at times in addition to written instructions?

8. State the questions you must answer when you prepare directions.

9. List five things that may keep your directions, even though they answer all the pertinent questions, from being understood.

10. State how the attitude of the person giving directions can affect the outcome.

11. List three benefits of rotating duty assignments.

**049. Differentiate between good and bad approaches to human relations.**

**Foundation for Good Human Relations.** Human relations on the job are a major and sensitive responsibility of the supervisor; you are completely aware that there are differences among human beings such as sex, race, background, and creed. You should know that people consider their jobs as their careers. They expect such things as a fair evaluation of their performance, equal opportunity to get ahead, and greater responsibilities to do important tasks and to have new job experiences. They desire status, the feeling of importance, and the desire to belong to a group. They also want economic and emotional security.

When workers find their status or pay check threatened, they know that something is wrong. They are more likely to accept change if you prepare them for it. You should try to keep a calm environment for people to work in. Keep rumors down by keeping your workers informed.

*Let workers know where they stand.* All workers need to know how they are getting along if they are to be happy and satisfied with their jobs. This includes whether workers know they are doing a good job or not. How can you do this? First, you can take an interest in your workers and get to know each one personally. Secondly, you can have periodic talks with each worker and see that each knows the job requirements. How often you contact your workers and how close the personal relationship that you maintain depend upon the individual work situations. Remember, there is a delicate balance between overfamiliarity and friendship. You must use good judgment or risk severe criticism that damages both morale and production in your unit.

*Give credit when due.* Recognizing individual effort is another technique that aids you in maintaining good job relations. Experience has proved that this technique gets good results, and supervisors who ignore it create problems such as loss of interest among their workers. But, knowing the technique and knowing how to put it to use are two different things. Giving credit when due is a good idea—but how do you do it? There are many ways. Here are some of them: (1) give workers a pat on the back and a little praise when they do a good job; (2) use letters of appreciation and commendation; (3) recommend outstanding performance ratings; (4) encourage the use of both the military and civilian suggestion programs, which can result in cash awards or other forms of recognition for improvements developed by your people; and, (5) recommend deserving personnel for promotion, upgrading, and better assignments.

*Inform workers in advance.* You need to inform your workers, of changes that affect them in advance. You can do this by personal contact with the individual, by written notices or bulletins, or by informal meetings and discussions. The last method is good. but calling workers together in a meeting to present a change does not automatically win their support and approval. You must get their interest and participation. If possible, get the workers in on the planning for the changes. Encourage them to contribute their ideas and "pitch in" to meet the problem. The supervisor's attitude and conduct, in general, greatly influences the workers' willingness to cooperate.

*Gain the workers' confidence.* Take a personal interest in each worker; be friendly, helpful, and fair in your dealings; encourage the workers to come to you with their problems, and take action on their problems if possible.

When properly used, these techniques can be of great assistance to you. But remember, "No two people are exactly alike." You must get to know your workers and understand their individual differences and needs. Study each individual. Learn the personal interests and problems of each worker and know what his or her reactions will be. You can then treat each worker as an individual.

**Exercises (049):**

1. Mark the following statements with a "G" for good techniques of human relations or "B" for bad techniques of human relations.

a. ____ Do not bother a worker who is doing a good job.
b. ____ Get to know each worker personally.
c. ____ Have short periodic talks with workers to be sure they know their job requirements.
d. ____ Check on what your workers are doing several times a day.
e. ____ Stop and "shoot the breeze" with your workers frequently.
f. ____ Get to be good buddies with at least some of your workers.
g. ____ Make sure you praise a worker who does a good job.
h. ____ Have workers turn in a suggestion if they come up with an improved way of doing a job.
i. ____ Do not be afraid to give exceptional workers outstanding performance ratings.
j. ____ When a change is needed, decide on the change and then make it.
k. ____ Ask your workers for suggestions when you find current procedures are not getting the work out on time.
l. ____ Try to treat each worker the same way the worker treats you.
m. ____ Don't get involved with the problems of workers unless they ask you for help.

**050. List methods you should avoid when solving a problem and specify the steps to take to solve a problem.**

**How to Handle a Problem.** We are surrounded with problems. Some are small; others are large. Some maybe simple; others are so complex that there seems to be no way to solve them. Fortunately, the Air Force has developed tried and true procedures which work in solving 99 percent of the problems that you are apt to encounter on the job. Unfortunately, some supervisors have not studied these methods. Instead, they use methods of their own.

*The wrong way.* There are six methods used to face problems which almost always end in disaster. These are shown in Figure 3-1, "How Sgt Blow Faces Problems." Believe it or not, some supervisors, and individuals too, use one or more of these methods when faced with a problem. Sgt Blow, in Figure 3-1, ignores the problem. He also uses method number 4 (he runs away very often during duty hours to the NCO club). A supervisor should be on the job during duty hours, not goofing off. You can see by his shape that Sgt Blow often uses method number 6. People who can't solve their problems can very easily fall into the bad habit of overeating, overdrinking, or taking drugs. In the figure, you can see how important Sgt Blow thinks he is. He is the big man with the big cigar who looks down his nose at the little man; no doubt Sgt Blow's unit is like a sinking ship. The tombstone, in the figure, is the result of using those unwise methods of problem solving. His section is rated unsatisfactory and Sgt Blow is blown away, but he never learns that he is the reason why. When asked why he lost his job, he uses method number 3 and blames the people who worked for him as the reason for his section's failure.

*The right way.* The procedures you should use to solve problems are summarized in Table 3-1, How to Handle a Problem. Notice that the table is made up of five main steps. These steps are subdivided into many substeps. Study these steps to problem solving and use them as you solve the problems that evolve around you.

**Exercises (050):**

1. List six methods to avoid when you must solve problems. These steps do not have to be in any order—all are equally bad.
   a.

   b.

   c.

   d.

   e.

   f.

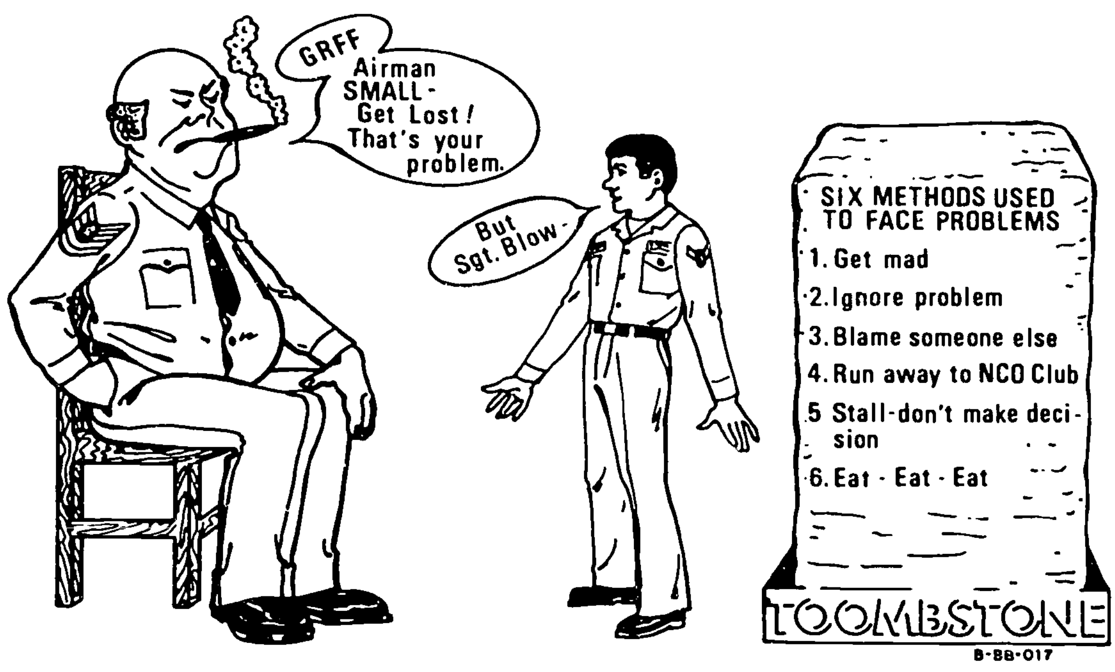


Figure 3–1. How Sgt Blow Hart faces problems.

2. Indicate the problem solving step from Table 3-1 during which the actions occur by entering the proper letter in the space provided.

Problem Solving Steps

a. Define the problem.
b. Get the facts.
c. Weigh and decide.
d. Take action.
e. Check results.

____ (1) Consult with other workers.
____ (2) Act on selected solution.
____ (3) Must be stated in specific terms.
____ (4) Analyze the facts.
____ (5) Review work records.
____ (6) Correct a faulty procedure.
____ (7) Establish relationship between facts.
____ (8) Correct any obvious weakness immediately.
____ (9) Be careful of preconceived ideas.
____ (10) Leads to setting objectives.
____ (11) Select the action to take.
____ (12) Observe job being done.
____ (13) May have overlooked a pertinent fact.

TABLE 3-1
HOW TO HANDLE A PROBLEM

1. DEFINE THE PROBLEM.

    a. What is the real problem.
    b. Write it on paper.

2. GET THE FACTS--ALL THE FACTS.

    a. Review the record.
    b. Find out what rules and regulations apply.
    c. Talk with individuals on both sides.
    d. Get opinions and feelings.
    e. Be sure you have the whole story.

3. WEIGH AND DECIDE.

    a. Fit the facts together.
    b. Consider their bearing on each other.
    c. What possible actions are there?
    d. Check practices and policies.
    e. Consider the objective and the effect on each individual or group and on work unit.
    f. Don't jump to conclusions.

4. TAKE ACTION.

    a. Are you going to handle this yourself?
    b. Do you need help in handling the situation?
    c. Should you refer this to your supervisor?
    d. Watch timing of your action.
    e. Don't pass the buck.

5. CHECK RESULTS.

    a. How soon will you follow up?
    b. How often will you need to check?
    c. Watch for changes in output, attitudes, and relationships.
    d. Did your action help work output?

PREVENT THE DEVELOPMENT OF PROBLEMS BY ELIMINATING THE CAUSES

8A-044

**051. List qualities you should try to instill in your workers and in given situations, distinguish between good and bad counseling principles.**

**Counseling Principles.** As a supervisor in the Air Force, you must have a basic understanding of counseling and guidance. This is because you are required to deal with people. You, as a counselor, must be able to interpret and explain the counselee's actions in terms of motive or cause if you expect to help the counselees understand themselves and solve their problems. To achieve this, you must be on the alert for causes. Surface effects like "coming in late" and "will not work" only indicate that a worker has a problem. They indicate that you must dig deep and try to find out what the cause is. In discussing the problem with the worker, you must ask yourself, "What is the basic cause, reason, motive, or consideration that has made this person behave as he or she does?"

When you learn the principles of counseling, you avail yourself of a method which helps you put your finger on the real problem. It also gives you a clue to the answer to the problem. And better still, you gain an insight into the causes of potential problems and the key to problem prevention.

People must make decisions one way or the other every day of their lives. The tossup type of decisions are the hardest to make. Airman Joe Watts was on KP and had to separate truckloads of potatoes into a good pile and a bad pile. When he asked his supervisor to relieve him from that duty, he said, "I don't mind the work, but those decisions are driving me nuts. I can't get them off my mind and can't go to sleep thinking about them. My production has dropped 50 percent."

Some people have the ability to make decisions that improve their way of life. Others make decisions that are self-destructive. As a supervisor, you must help the self-destructive-type individuals learn how to make decisions that will improve their way of life and their image of themselves. When they learn how to make proper decisions, their self qualities will change from negative to positive. Your purpose in counseling should be to produce the following positive self-qualities in your workers:

- Self motivation.
- Self understanding.
- Self responsibility.
- Self directivity.
- Self productivity.
- Self satisfaction.

Counseling and "chewing out" are not the same thing. Why not? Because a "chewing out" causes resentment and frustration among the "chewees" and seldom improves their attitudes or production. On the contrary, a bawling out usually causes anger, a negative attitude, and a reduction of production.

The essence of counseling is the ability to mentally and emotionally put yourself in the place of the person you wish to counsel. You must gain an understanding of this person's problem by looking at it as though you were seeing through his or her eyes.

This viewpoint is not an easy one to acquire, but it is basic to true counseling. It is called empathy. Empathy in no way means "sympathy" or "coddling." After all, remember that you are dealing with adults, not children. Whatever they have or have not done, they want to be treated as adults.

Certain principles are followed by every good supervisor-counselor. Probably the most successful of these principles, which you too should learn and practice, are these. The order in which they are listed is not, in itself, especially significant.

*Counseling Principles*

- Respect each worker.
- Act friendly—smile.
- Listen to worker.
- Do not threaten worker.
- Do not argue with worker.
- Encourage worker to talk about the problem.
- Let worker express attitudes and emotions.
- Relieve worker from fears and anxieties.
- Help worker to help themselves.
- Be patient and understanding.
- Stress mutual cooperation.
- Stress joint responsibility.
- Use problem-solving methods.
- Do not gossip about problem.

**Exercises (051):**

1. List self-qualities you, as a supervisor, wish to produce in your workers.

2. Answer true or false. Counseling is chewing out a person for something he or she has done wrong or something he or she has failed to do. State the reasons for your answer.

3. In the following exercises place an X in the space provided for bad counseling principles.

____ a. MSgt Jones pounds the table when telling A1C Jack Smith about his error.
____ b. Supervisor Kelley is firm but friendly.
____ c. SSgt Judy Sand tells her workers that they should be seen but not heard.
____ d. TSgt Bills says, "Let them talk so you can get the goods on them."
____ e. Do not argue with worker during a counseling session.
____ f. Tell the boys what Amn Joan Grey said during her interview.

**052. Distinguish between situations in which you should counsel a subordinate and those in which you should not counsel, and list the steps to follow in solving a given personnel problem.**

**Problems of the Individual and the Supervisor.** An individual may be a poor producer on the job because of personal problems. These problems can include, but are not limited to, overspending, excessive drinking, and frustration in not being able to reach a goal, among others. Obviously, workers who have problems which they are not able to manage may bring their problems onto the job with them. If they do so, they cannot concentrate properly on their jobs, because their minds will keep going back to their personal problems. This is where you come in as a supervisor. You can—and should try to—help these people by trying to find out the real reason for their low productivity. Besides, by working to help such a subordinate, you will be helping the productivity of your whole shop. In any event, when you dig deep, you will usually find that what appears to be the problem (effect) is not the real one (cause). Consider, for example, Airman Johnny Smith, who is making many errors. On the surface, it may seem that he is just a lazy fellow—one who doesn't really care. Actually, however, his true problem is the collector who is hounding him for falling behind in the payment of his bills.

As a supervisor, you don't have to be a "know it-it-all" to solve such personal problems. Each Air Force Base has referral agencies that specialize in various fields. Therefore, you can refer the troubled worker to the appropriate agency. Some of these agencies are the Legal Office, Red Cross, Social Actions, Education Office, Drug Information, Chaplain, Career Advisor, and Family Services. Still, it is your responsibility as a supervisor—no one else's—to find out the real, underlying problem. An important, fundamental tool which you can use to do this is the counseling interview.

**The Counseling Interview.** The interview is the heart of the counseling process. Why? Because it is, usually, only while the counseling interview is in process that the counselor and counselee meet directly, personally, and jointly to discuss and attempt to resolve—or at least alleviate—the counselee's problem. Since good interviewing is essential to effective counseling, every supervisor should be familiar with its basic principles.

These principles include preparing for the interview, conducting the interview, closing the interview, evaluating the success of the interview, recording the interview, and following up on the interview.

*Preparing for the interview.* In getting ready for the interview, you should collect all the information possible about the counselee. You should choose a nice quiet place to meet where there are no interruptions and you should get yourself mentally ready.

*Beginning the interview.* When you begin the interview, it is important that the counselee be provided with relief from distrust, tension, and insecurity. To this end, certain techniques are valuable.

*Establishing rapport (harmony).* "Rapport" can be defined as that atmosphere of understanding, mutual trust, and confidence that enables people to work together effectively. Regarding rapport, the initial meeting between the counselor and counselee is often of crucial importance. You can "help things along" by rising to your feet, smiling, extending your hand when the situation demands, and stepping forward to meet the counselee. If you do these things sincerely, you will go a long way toward gaining the confidence and overcoming any defensiveness the counselee may feel at the outset.

*Conducting the interview.* During the interview, listen attentively to the counselee. Counselors must listen! This is basic. It is likely that they will learn very little by talking themselves, but they may learn a great deal about people by listening to everything they have to say. In fact, numerous studies made in public schools and in private industry have shown that one of the most frequent errors made by professional counselors is that they talk too much and listen too little. After all, communication is a two-way process, but the most important input is that of the counselee. As the interview develops, you should follow this four-step procedure:

(1) Analyze the problem and situation thoroughly.
(2) Define the limits of the problem.
(3) List any referral sources needed.
(4) Outline a course of action for solving the problem.

*Closing the interview.* If it is possible, have the counselee summarize the interview. If the counselee is cooperating in the counseling process, you may succeed in getting him or her to summarize what has been learned. Still, if the counselees fails to cooperate, you may need to make the summary yourself.

*Evaluating the success of the interview.* Immediately after the interview, you can take stock and quietly congratulate yourself on having been successful to some degree if the counselee leaves with:

*a.* A plan of action.
*b.* A feeling of accomplishment.
*c.* The feeling that he or she may return at any time.

In the final analysis, the best criterion for evaluating the success of any interview is the results obtained. The results are beneficial when the counselee's problem no longer exists or when a satisfactory adjustment has been made, so that the condition no longer negatively affects the person's achievement.

*Recording the interview.* Use the appropriate evaluation form to record information that you get during the interview. Usually, it is considered best not to make notes during the interview. But immediately after the interview, you should record the information in some way so that you will remember all the points covered.

*Following up the interview.* At this point, you DO what you told the counselee you would do to follow up on progress. Frequently counselors check just superficially, noting that some improvement was made. This will not suffice. Your follow up should be a thorough investigation to determine whether or not the counselee's actions are the ones agreed upon during the interview. When following through in this manner, you may find a need for further consultation. Then you can assist the counselee to continue on a satisfactory course of action.

**Exercises (052):**

1. Write T for true or F for false beside each letter-coded item related to the problems of the individual and the supervisor which can lead to the setting up of a counseling interview between them.

____ a. Workers with problems that they can't manage may bring them on the job with them.
____ b. As a supervisor-counselor, you can help workers with problems most by discovering the real reason for their problems, then help them resolve the problems.
____ c. It helps for supervisor-counselors to be "know-it-alls" as they try to solve their workers' personal problems.
____ d. Supervisors can refer troubled workers to various referral agencies on base who are better able to help them resolve their problems than the supervisor.
____ e. In any case, it is the supervisor's responsibility still—no one else's—to find out the real, underlying problem.

2. Read the following problem situation, which is based on a personal problem of A1C Jim Johnson who works for you. On a plain sheet of paper, list the steps you will follow to solve this problem.
Situation: You are supervisor of the electric shop. A1C Johnson works for you. His records indicate that he is highly qualified to do the job. But, lately, he has been wearing wrinkled uniforms and often needs a haircut and shave. He is also performing below his capability, seems sleepy most of the time, and complains of having too many bills to pay. How are you going to handle this problem?

**053. Specify important considerations in determining and using performance standards.**

**Performance Standards.** Workers have a right to know what their supervisors expect of them. They should be told

how their work is to be judged. The purpose of performance standards is to define the quality and quantity of work that must be put into a job for it to be satisfactorily completed.

*Determining standards*. Performance standards should be realistic and practical. Quite often people have difficulty when they set up standards because they put too much emphasis on the operating details of the job rather than on the results. The objective should be to set levels of performance that will get the unit's mission done. Reasonable standards stimulate people to work. Workers are neither overloaded nor underloaded. Thus, when workers complete a job that is based on a reasonable standard, they have a sense of satisfaction of a job well done. When workers are overloaded, there are accidents, errors, fatigue, high turnover of personnel, resentment, and slowdown. The situation is just as bad when workers do not have enough to do. The results here are usually mischief, too high a cost of operation, grievances, and absenteeism. The factors of worker overload and underload are important when you set up the level of performance standards.

Performance standards for each work operation must describe what is acceptable performance. They should be set at the level of performance that can be expected of any qualified, competent worker. Workers become frustrated and will quit trying to reach a goal if the performance level is set too high. The requirement must be at a level that can be reached by average workers. There should be room for exceptional workers to perform above the requirement.

Do not base the requirement level upon the performance of the worker who is now assigned to the position. This would assume that the worker is meeting all the requirements of the position at an acceptable level. If such a worker has unusually high qualifications, it will penalize other workers' outstanding performance as being only satisfactory, and penalizes future workers who are competent but not outstanding by rating their performance as unacceptable. On the other hand, if the worker's performance is actually not good, the established level of satisfactory performance will be too low.

Another thing that you must consider when you are determining performance standards is the fact that all workers do not produce an identical amount and quality of work. Rather, there is a range of performance which should be considered as acceptable. Performance that is below this level is below average and may possible be unacceptable. Performance that is above this level is considered above average and may possibly be outstanding. The established range should be realistic.

You can use the following procedures to set up performance standards:

*a*. Select the tasks or major work factors of the job.

*b*. Decide tentatively what is reasonable to expect as to:

(1) Quantity of results in a given time.

(2) Quality of results in terms of how well the job must be performed.

(3) Manner of performance.

*c*. Discuss tentative requirements with:

(1) Workers assigned to the job.

(2) Your supervisors.

(3) Other supervisors who determine requirements for the same type of operation.

*d*. Check the possible effect of existing requirements in relation to:

(1) Trade or craft requirements.

(2) Management data.

(3) Requirements of higher echelons.

*e*. Review and formulate firm requirements that are fully understood by all workers affected.

*Using performance standards*. Performance standards must be used to be of any benefit. You must weigh the workers' performance continually against the standards and discuss it with them from time to time. You must then take action consistent with the workers' performance by (1) giving recognition to workers who exceed the standards, (2) helping workers who are below the standards by added training or other appropriate means, and (3) motivating workers who are doing acceptable work to get them to perform better if they are capable.

Several distinct benefits can be realized from the proper use of realistic performance standards. They set what is the least acceptable production goals for each worker. These goals help to give your workers a better attitude toward the work situation because they tend to create greater job satisfaction. Other advantages are these: they provide a sound basis for estimating future work capacity; they provide data for planning, organizing, and assigning work; they provide a basis for determining who needs more training and how much; and they provide a sound basis for personnel actions, and formal ratings such as APR's.

**Exercises (053):**

1. State the purpose of setting up performance standards.

2. Give two precautions that should be taken when setting up performance standards for a job.

3. If standards are set up that cause workers to be overloaded, what effects are likely to show up on the job?

4. What usually happens when job standards are set too low?

5. State the level of performance that should be set for a job.

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6. Why should you be careful not to use the worker now doing the job as your standard when setting performance standards?

7. State how you should allow for the fact that all workers do not produce the same amount and quality of work when you develop performance standards.

8. When setting up a job performance standard, whose opinions should be considered?

9. Once you have established performance standards, how do you benefit from them?

10. List four benefits that you can gain from the proper use of realistic performance standards.

**054. State the procedures used to get valid performance ratings to evaluate the performance of an airman and the requirements for submitting Airman Performance Reports.**

**Evaluation of Subordinate Personnel.** You as a supervisor must be willing to accept all the responsibilities that go with supervision. Often, one of the more difficult of these responsibilities is the evaluation of your personnel and the preparation of performance ratings. Many supervisors dread having to carry out this part of their jobs because, in a good deal of cases, the results leave much to be desired. On occasions, tempers flare, words fly, and friendly working relationships that are needed for good performance are lost or disrupted.

Some of the difficulties involved in the rating of personnel are relieved if the supervisor has prepared for the task. Probably the first and most important way to prepare your people for rating is to make sure that they understand the performance standards expected of them. When this aspect of their job is made clear, early in their assignment, they are not too apt to plead ignorance at rating time. An occasional suggestion or reminder is useful when some individuals tend to relax their standards. Also, an interview or counseling session proves valuable at times to improve attitudes, performance, or interest in becoming more skillful.

**Airman Performance Reports (APR's).** The basis for rating is observation, evaluation, and reporting. First, it is necessary that the performance of the individual be observed. These observations should be made over a long enough period of time to be sure that typical performance is observed. This consists of direct observation of the person's behavior, performance of duty, and work quality. If you can not make direct observations, you should try to get meaningful information from as many sources as possible.

Following your observations, you must evaluate the typical performance of the individual against an acceptable standard. Do not place too much emphasis on isolated instances of either poor or outstanding behavior. The significance of the event, as well as how often it occurs, must be weighed, to help you make up your mind on how well it represents the total performance. Each person must be judged in comparison with other persons who serve in the same grade and job.

After you have made your observation and evaluated the individual, you can write the performance report. The report should be made as objective as possible on the basis of your observations.

Performance reports are normally required when there has not been a report submitted for 1 year. Reports are also required when there is a change in the rating official, or when the individual's performance requires a referral report. Prior service enlistees must have an APR prepared 120 days after enlistment. Submission requirements are outlined in Table 3-1 of AFR 39-62, *Noncommissioned Officer and Airman Performance Report.*

Reports are to be made by a rater called the reporting official. This official is a commissioned officer, noncommissioned officer, a senior airman, or a civilian in the grade of GS-4 or higher. The rater is usually the ratee's immediate supervisor. Indorsements generally follow the chain of supervision. That is, the first indorser is the rater's rater, the second indorser is the first indorser's rater, and so on.

Performance reports are not to be used as a means of, nor as a basis for, disciplinary action. The reports become a part of the personnel records kept on an NCO or airman for administrative purposes. They contribute information concerning the individual's duty performance, which, with the rest of the individual's personnel record, is used as reference to such personnel actions as promotion, classification, and assignment.

*Referral report.* A report that contains any ratings in the lowest block (excluding Not Observed) in any one item of section III or an overall evaluation of 0 or 1 in section IV is a referral report. Any comments in the APR, or attachments, that refer to conduct incompatible with Air Force standards of personal conduct, character, or integrity are also referral reports. Referral reports can also be written for below standard duty performance, dress, bearing, judgment, leadership, supervisory responsibilities, or nonrecommendation for promotion or reenlistment. If there is a doubt as to whether the APR is a referral report, it should be made a referral report.

*Outstanding report.* An APR containing an entry by any rating official in the highest rating box (box 9) in section IV is considered outstanding. The APR rating reported by the final indorsing official is the rating that goes into the computerized Personnel Data System (PDS).

**Exercises (054):**

1. Why do many supervisors find rating their personnel a difficult job?

2. How can you prepare your workers for rating?

3. What are the basic requirements to develop a valid rating?

4. How should your observation of the ratee's performance be made for best results?

5. Explain why you should not rate the worker on isolated observations.

6. Who prepares the APR on an airman?

7. When would a ratee be shown an APR before it is completed?

8. When are APR's normally submitted?

9. What type of APR is it when the overall rating is 1?

10. If the rater rates the individual as outstanding (9) and the third indorsing official (final) rates the individual as 8, what is the computerized rating of the APR?

**055. State the procedures that apply to the preparation of APR's and identify the correct form to use.**

**Forms Used.** The forms used in preparation of an APR will depend on the airman's grade. The forms to be used are as follows:

*a.* AF Form 909, Airman Performance Report, is used to rate Senior Airman (SRA), Airman First Class (A1C), Airman (Amn), and Airman Basic (AB).

*b.* AF Form 910, TSgt, SSgt, Sgt Performance Report is used for Technical Sergeants (TSgts), Staff Sergeants (SSgts), and Sergeants (Sgts).

*c.* AF Form 911, CMSgt, SMSgt, MSgt Performance Report, is used for Chief Master Sergeants (CMSgts), Senior Master Sergeants (SMSgts), and Master Sergeants (MSgts). **Instruction.** For instructions on how to fill out these forms refer to Chapter 4 of AFM 39-62. Figures 3-2, 3-3, 3-4, and 3-5 show forms you will use, along with a statement in each block of the form, and will give you an idea of what information to fill in. It is relatively simple to fill out but for specific instructions or questions, always refer to the regulation as a guide.

Type the APR if possible. Otherwise, print or legibly write the entries in black or dark blue ink. No corrections or erasures are permitted in Section III and IV of the report. Corrections or erasures made on other parts of the report are authorized as long as there aren't too many. If the change changes sentence structure or meaning, it must be initialed by the evaluator who makes the change.

**Letter of Evaluation (LOE).** Sometimes a rater does not have a chance to fully observe a subordinate's performance and personal qualities during the reporting period. For example, the rater may change and there was not enough time passed since the closeout date of the last APR to require the submission of another APR. Another example would be when duty was performed under the supervision of someone other than the rater for part of the reporting period. In either case a LOE is submitted. Conditions that determine when to obtain or write an LOE are in Table 3-4 of AFR 39-62 along with rules that apply to LOEs. One of the more common rules that may apply to you is that LOEs must be submitted if the period of supervision is more than 60 days but less than 120 days.

LOEs along with additional indorsements and continuation sheets are submitted on AF Form 77, Supplemental Evaluation Sheet. An example of Af Form 77 is in Figure 3-6. Use the same procedures to fill out this form as you do on the APR forms.

**Exercises (055):**

1. Place the form number, 909, 910, 911, or 77, in the space provided to show the form used for the situation described below.

____ a. An airman who has been on active duty for 12 months is due an APR.
____ b. Major Neal is required to write SMSgt Blackman's APR.
____ c. You write SRA Watt's APR.
____ d. SRA Brown's APR is due on March 5 and he will be promoted to Sgt on March 1.
____ e. Sgt Anderson has been under your supervision for 73 days and has received a PCS assignment.

**I. RATEE IDENTIFICATION DATA** *(Read AFR 39-62, Vol I, carefully before completing any item.)*

| 1. NAME (Last, First, Middle Initial) | 2. SSAN | 3. GRADE |
|---|---|---|
| Watts, Betty J. | 000-00-0000 | A1C |

| 4. ORGANIZATION, COMMAND, LOCATION AND PAS CODE | 5. PERIOD OF REPORT AND SUPERVISION | | 6. REASON FOR REPORT |
|---|---|---|---|
| 35th Cmbat Support Group (TAC) | FROM 12 Dec 77 | NO. OF DAYS 190 | CHANGE OF RATER |
| George AFB California | THROUGH 13 Aug 78 | | ANNUAL |
| GBOTFD4J | | | X DIRECTED BY HQ USAF |

| 7. PAFSC | 8. DAFSC | 9. CAFSC |
|---|---|---|
| 81150A | 73250 | 73250 |

**II. JOB DESCRIPTION:** Wing/Base Records Clerk. Responsible for the filing and maintenance of approximately 400 Unit Personnel Records Groups. Prepares "Statements of Service". Conducts records reviews. Assists NCOIC in controlling access to Unit Personnel Records Groups.

**III. EVALUATION OF PERFORMANCE**

| Factor | | N/O | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. PERFORMANCE OF DUTY: Consider the quantity, quality, and timeliness of duties performed as described in Section II. | RATER | | | | | | | | | X | | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 2. HUMAN RELATIONS: Consider how well ratee supports and promotes equal opportunity, shows concern and is sensitive to needs of others. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 3. LEARNING ABILITY: Consider how well ratee grasps instructions, communicates (oral and written), and understands principles and concepts related to the job. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 4. SELF-IMPROVEMENT EFFORTS: Consider how well ratee progresses in on-the-job training and in other efforts to improve technical knowledge and educational level. | RATER | | | | | | | | X | | | |
| | 1ST INDORSER | | | | | | | | X | | | |
| 5. ADAPTABILITY TO MILITARY LIFE: Consider how well ratee adapts and conforms to the requirements of military duties not directly related to the job. | RATER | | | | | | | | | X | | |
| | 1ST INDORSER | | | | | | | | | X | | |
| 6. BEARING AND BEHAVIOR: Consider the degree to which ratee's bearing and behavior on and off duty improve the image of Air Force airmen. | RATER BR | | | | | | | | | X | | |
| | RATER BH | | | | | | | | | | X | |
| | 1ST INDORSER BR | | | | | | | | | X | | |
| | 1ST INDORSER BH | | | | | | | | | X | | |

**IV. OVERALL EVALUATION**

How does the ratee compare with others of the same grade and Air Force specialty? Potential for promotion and increased responsibility are essential considerations in this rating.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| RATER | | | | | | | X | | | |
| 1ST INDORSER | | | | | | | X | | | |
| 2D INDORSER | | | | | | | | X | | |
| 3D INDORSER | | | | | | | | X | | |

AF FORM SEP 79 909 PREVIOUS EDITIONS ARE OBSOLETE.

**AIRMAN PERFORMANCE REPORT**
**(Airman Basic thru Senior Airman)**

Figure 3–2. AF Form 909.

**I. RATEE IDENTIFICATION DATA** *(Read AFR 39-62, Vol I, carefully before completing any item.)*

| 1. NAME (Last, First, Middle Initial) | 2. SSAN | 3. GRADE |
|---|---|---|
| SELLMAN, JAMES S. | 000-00-0000 | TSGT |

**4. ORGANIZATION, COMMAND, LOCATION AND PAS CODE**

35th Cmbt Spt Gp (TAC)
George AFB California
GBOTFD4J

**5. PERIOD OF REPORT AND SUPERVISION**

| FROM | THROUGH | NO. OF DAYS |
|---|---|---|
| 14 Aug 77 | 5 Jun 78 | 222 |

**6. REASON FOR REPORT**

- X CHANGE OF RATER
- ANNUAL
- DIRECTED BY

| 7. PAFSC | 8. OAFSC | 9. CAFSC |
|---|---|---|
| 73270 | 73270 | 73270 |

**II. JOB DESCRIPTION:** Wing/Base, NCOIC, Records Unit. Responsible for insuring the accountability, maintenance and control of approximately 5500 Unit Personnel Records Groups. Schedules and conducts records reviews. Provides required support to the remaining units within the CBPO. Supervises eight personnel. Prior Duty: DAFSC - 73270, Wing/Base, NCOIC, Separations Unit.

**III. EVALUATION OF PERFORMANCE**

| Factor | Evaluator | N/O | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. PERFORMANCE OF DUTY: Consider the quantity, quality, and timeliness of duties performed as described in Section II. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | | X |
| 2. HUMAN RELATIONS: Consider how well ratee supports and promotes equal opportunity, shows concern and is sensitive to needs of others. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 3. TRAINING: Consider how well responsibilities are discharged as an OJT supervisor or trainer and in other efforts to improve technical knowledge and educational level. | RATER | | | | | | | | | X | | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 4. SUPERVISION: Consider how well ratee supervises, leads, uses available resources, communicates (oral and written), and maintains good order and discipline. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 5. ACCEPTANCE OF NCO RESPONSIBILITY: Consider ratee's acceptance of responsibility for personal actions and those of subordinates. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 6. BEARING AND BEHAVIOR: Consider the degree to which ratee's bearing and behavior on and off duty improve the image of Air Force noncommissioned officers. | RATER BR | | | | | | | | | | X | |
| | RATER BH | | | | | | | | | | X | |
| | 1ST INDORSER BR | | | | | | | | | | X | |
| | 1ST INDORSER BH | | | | | | | | | | X | |

**IV. OVERALL EVALUATION**

How does the ratee compare with others of the same grade and Air Force specialty? Potential for promotion and increased responsibility are essential considerations in this rating.

| Evaluator | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| RATER | | | | | | | | | X | |
| 1ST INDORSER | | | | | | | | | X | |
| 2D INDORSER | | | | | | | | | X | |
| 3D INDORSER | | | | | | | | | X | |

AF FORM SEP 79 910 PREVIOUS EDITIONS ARE OBSOLETE. TSGT, SSGT, SGT PERFORMANCE REPORT

Figure 3-3. AF Form 910.

| I. RATEE IDENTIFICATION DATA (*Read AFR 39-62, Vol I, carefully before completing any item.*) | | |
|---|---|---|
| 1. NAME (*Last, First, Middle Initial*)<br>TURVEY, DENNIS R. | 2. SSAN<br>000-00-0000 | 3. GRADE<br>SMSgt |

| 4. ORGANIZATION, COMMAND, LOCATION AND PAS CODE | 5. PERIOD OF REPORT AND SUPERVISION | | 6. REASON FOR REPORT |
|---|---|---|---|
| 35th Cmbt Spt Gp (TAC)<br>George AFB CA<br>GBOTFD4J | FROM 14 Aug 77<br>THROUGH 13 Aug 78 | NO. OF DAYS 330 | CHANGE OF RATER<br>X ANNUAL<br>DIRECTED BY ____ |
| | 7. PAFSC 81199 | 8. OAFSC 73299 | 9. CAFSC 73299 |

II. JOB DESCRIPTION: Wing/Base, NCOIC, Customer Assistance Section. Reviews and controls all incoming correspondence, establishes priorities, and ensures timely completion of all tasks. Administers casualty services and military and personal affairs programs. Exercises general management over three units: Customer Service Unit, Records Unit and Personal Affairs Unit. Supervises six personnel. Additional Duty: Squadron Security NCO.

III. EVALUATION OF PERFORMANCE

| Factor | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. PERFORMANCE OF DUTY: Consider the quantity, quality, and timeliness of duties performed as described in Section II. | RATER | N/O | | | | | | | | | | X |
| | 1ST INDORSER | | | | | | | | | | | X |
| 2. HUMAN RELATIONS: Consider how well ratee supports and promotes equal opportunity, shows concern and is sensitive to the needs of others. | RATER | | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 3. TRAINING: Consider how well responsibilities are discharged as an OJT supervisor or trainer and in other efforts to improve technical knowledge and educational level. | RATER | N/O | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 4. EXECUTIVE ABILITY: Consider ratee's judgment, decisiveness, ability to communicate (oral and written), and effectiveness in supervising and leading. | RATER | N/O | | | | | | | | | | X |
| | 1ST INDORSER | | | | | | | | | | X | |
| 5. ACCEPTANCE OF NCO RESPONSIBILITY: Consider ratee's acceptance of responsibility for personal actions and those of subordinates. | RATER | N/O | | | | | | | | | X | |
| | 1ST INDORSER | | | | | | | | | | X | |
| 6. BEARING AND BEHAVIOR: Consider the degree to which ratee's bearing and behavior on and off duty improve the image of Air Force noncommissioned officers. | RATER | BR / BH / N/O | | | | | | | | | | X |
| | 1ST INDORSER | BR / BH | | | | | | | | | | X |

IV. OVERALL EVALUATION

How does the ratee compare with others of the same grade and Air Force specialty? Potential for promotion and/or increased responsibility are essential considerations in this rating.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| RATER | | | | | | | | | | X |
| 1ST INDORSER | | | | | | | | | X | |
| 2D INDORSER | | | | | | | | | X | |
| 3D INDORSER | | | | | | | | | X | |

AF FORM SEP 79 911 PREVIOUS EDITIONS ARE OBSOLETE. CMSGT, SMSGT, MSGT PERFORMANCE REPORT BE-911

Figure 3–4. AF Form 911.

V. RATER'S COMMENTS FACTS AND SPECIFIC ACHIEVEMENTS: Illustrate the way the ratee typically carries out any duties whether assigned or not assigned. Do not recapitulate duties performed; tell how the ratee performs. STRENGTHS: Describe those positive aspects of the individual's performance deserving special note. RECOMMENDED IMPROVEMENT AREAS: Clearly specify whether references are to serious deficiencies, faults, bad habits, or to occasional tendencies. The value of such comments will be vastly increased if they include an indication of what progress, if any, has occurred as a result of bringing the weaknesses to the individual's attention before preparing the report. An entry under this heading does not require referral (paragraph 3-10) unless it contains comments of the type defined in paragraph 2-9c. EDUCATIONAL AND TRAINING ACCOMPLISHMENTS: Comment on any special training or courses of instruction the ratee completed or actively participated in during the reporting period. This also includes off-duty educational achievements. If applicable, comment on the manner in which the ratee discharges OJT responsibilities, whether as an OJT supervisor, trainer or trainee. SUGGESTED ASSIGNMENTS: Apply your evaluation of the individual for subsequent utilization. Be specific. OTHER COMMENTS: Include those comments required by paragraph 4-6b(2). Add any comments not covered above which add to the report and which are not prohibited by paragraph 3-12.

| NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND AND LOCATION | DUTY TITLE | DATE |
|---|---|---|
| RICHARD L. MURPHY, CMSgt. USAF<br>35th Cmbt Spt Gp (TAC)<br>George AFB, California | Asst Chief, Customer Assistance Section | 13 Aug 80 |
| | SSAN: 000-00-0000 | SIGNATURE: Richard L. Murphy |

VI. 1ST INDORSER'S COMMENTS ☐ CONCUR ☒ NONCONCUR

Indicate concurrence or disagreement with the report. Significant disagreement with ratings must be substantiated by specific comment. In addition, include any comments that will increase the value of the report.

| NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND AND LOCATION | DUTY TITLE | DATE |
|---|---|---|
| MICHAEL C. WHITE, GS-9, DAF<br>35th Cmbt Spt Gp (TAC)<br>George AFB CA | Chief, Customer Assistance Section | 15 Aug 80 |
| | SSAN: 000-00-0000 | SIGNATURE: Michael C. White |

VII. 2D INDORSER'S COMMENTS ☒ CONCUR ☐ NONCONCUR

Indicate concurrence or disagreement with the report. Significant disagreement with ratings must be substantiated by specific comment. In addition, include any comments that will increase the value of the report.

| NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND AND LOCATION | DUTY TITLE | DATE |
|---|---|---|
| ROGER S. SALISBURY, Major, USAF<br>35th Cmbt Spt Gp (TAC)<br>George AFB, California | Chief, CBPO | 15 Aug 80 |
| | SSAN: 000-00-0000FR | SIGNATURE: Roger S. Salisbury |

VIII. 3D INDORSER'S COMMENTS ☐ CONCUR ☐ NONCONCUR

THIS SECTION NOT USED

| NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND AND LOCATION | DUTY TITLE | DATE |
|---|---|---|
| | | |
| | SSAN | SIGNATURE: RSS |

Figure 3–5. Reverse of AF Forms 909, 910, and 911.

**I. RATEE IDENTIFICATION DATA**

| 1. NAME (Last, First, Middle Initial) | 2. SSAN (Include suffix) | 3. CURRENT GRADE |
|---|---|---|
| Archer, Walter W | 000-00-0000 | TSgt |

| 4. DAFSC | 5. DUTY TITLE OR TITLE OF SPECIAL OR ADDITIONAL DUTY |
|---|---|
| 73270 | Wing/Base NCOIC, Records Unit |

**II. TYPE OF REPORT** *(Check appropriate block in Part A.) (Complete Part B as required.)*

| | | | | |
|---|---|---|---|---|
| A | [ ] SUPPLEMENTAL SHEET *(Complete Part B, Items 1 and 2 only.)* | | [X] LETTER OF EVALUATION *(Complete Part B, Items 1 thru 4.)* | |
| B | 1. FROM 10 Mar 80 | 2. THRU 28 May 80 | 3. REPORT IS [X] MANDATORY | [ ] OPTIONAL |
| | 4. REASON FOR REPORT | [X] CRO 60 OR MORE DAYS SUPERVISION | [ ] SPECIAL OR ADDITIONAL DUTY | |
| | | [ ] CRO LESS THAN 60 DAYS SUPERVISION | [ ] PIPELINE STUDENT | |
| | | [ ] GEOGRAPHICAL SEPARATION/TDY | [ ] OTHER - EXPLAIN IN SECTION III | |

**III. COMMENTS**

The AF Form 77 should be typed. If no typewriter is available, entries must be printed or legibly written in reproducible ink (black or dark blue only). In all cases, confine comments to the space provided on the form. Sign the original in reproducible ink (black or dark blue only); if additional copies are required the remaining copies may be signed, initialed, or stamped "SIGNED." When rendering an LOE, use the heading "FACTS and SPECIFIC ACHIEVEMENTS" followed by appropriate comments. This heading is mandatory on all LOEs. Omit other headings entirely if not followed by comments. Headings must be entered in the order shown in figure 3-3.

**IV. EVALUATOR IDENTIFICATION DATA**

| 1. NAME, GRADE, BRANCH OF SERVICE, ORGANIZATION, COMMAND, LOCATION | 2. DUTY TITLE | 3. DATE |
|---|---|---|
| ROGER S. SALISBURY, Major, USAF<br>35th Cmbt Spt Gp (TAC)<br>George AFB CA 92392 | Chief, CBPO | 28 May 80 |
| | 4. SSAN 000-00-0000 | 5. SIGNATURE Roger S. Salisbury |

AF FORM MAY 79 77 REPLACES AF FORM 77A, NOV 74, WHICH IS OBSOLETE. SUPPLEMENTAL EVALUATION SHEET

Figure 3-6. AF Form 77.

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2. How do you prepare an APR on an airman if no one is available to type it?

You are writing an APR on an airman and you make a mistake on an entry in section III. State how you correct this entry.

When writing the comments on an APR, you misspell a word that can be corrected without changing the meaning of the sentence. What action is required in this case?

**056. State how to use job performance appraisals for civilian personnel.**

The job performance appraisal system (JPAS) establishes performance standards and identification of critical and noncritical job performance elements used as a basis for personnel decisions to reward, assign, promote train, retrain or remove employees. Personnel management uses the performance appraisal as an evaluation device for all civilian employees. The appraisal procedures are uniform throughout the Air Force. But each supervisor must prepare a work plan that describes job requirements and performance standards expected for each employee. As a supervisor of civilian employees, you must review each of your worker's performance periodically.

**Performance Appraisals for Civilian Personnel.** You should be familiar with AFR 40–452, *Performance Appraisal System.* This regulation explains the civilian appraisal system and establishes the supervisor's responsibility to appraise civilian workers.

A performance appraisal is due for each civilian employee annually unless circumstances require a change to the appraisal period. As the rating supervisor, you must review the mission of your unit to determine if the job descriptions of each employee accurately describe the duties and responsibilities required to complete the mission. You then prepare an AF Form 1282, Job Performance Appraisal, for each civilian employee under your supervision.

*Preparing AF Form 1282.* The AF Form 1282 is the document used to record an employee's work plan and overall performance rating. You should read the instructions that give you general information about the work plan and rating sections on page 1 of the form. Then, complete the employee identification part of the form as specified on page 1. Next, you must type in the names, grades, and duty titles of the supervisor and reviewing official in the work plan authentication section. When you complete the work plan, you, the supervisor, reviewing official, and the employee should sign and date this section. Now, let's discuss other parts of the AF Form 1282.

*a.* Part I—work plan job performance elements. Enter the employee's job performance elements on page 2, Part I. The elements are requirments of duty performance and are normally taken from the employee's job description. They are further broken down into critical and noncritical.

Critical elements are job performance elements that management considers very important. Failure of the critical elements may require remedial action and denial of merit pay or within-grade increase, and may be the basis for removing, reassigning, or demotion of an employee. Noncritical elements are job performance elements used to determine the overall performance level. Performance below the minimum standard requires counseling the employee.

*b.* Part II—work plan and performance standards. This is a written statement of the quantity and quality of performance expected for the job element listed on page 2 of the AF Form 1282. There may be more than one standard for a single job performance element.

*c.* Part III—performance substantiation and overall performance rating. When the employee's rating is made, you must write supporting evidence for the elements evaluations on page 4, part III of the form. This means that you need to compare the employee's job standard with the actual performance of the employee throughout the year. This is where you enter your comments on all job performance elements listed on page 2 of AF Form 1282. Then assign an overall performance rating.

Performance appraisals were designed to be used as the first step in a total management system to identify and correct work performance problems. They help you plan OJT classes and request formal training when needed. They can also recognize and reward quality performance of outstanding civilian employees.

Wouldn't you want your supervisor to tell you what you aren't doing right so that you can correct it? Then you should never let the ratings on the appraisal be a surprise to *your* employees. You must take the time with your employees and discuss their performance with them. Every few months you should check and revise job performance elements and performance standards that no longer apply.

**Exercises (056):**

1. What type of device is the job performance appraisal?

2. How often are job performance appraisals due?

3. What will determine the duties and responsibilities of each civilian employee job description?

4. What are the two classes of job performance elements?

5. Failure of what class of job performance element requires remedial action?

6. What part of the AF Form 1282 will the supervisor enter an overall performance rating?

## 3-2. Training

The Air Force OJT program is a systematic, reportable application of the craftsman-apprentice relationship, by which the trainee acquires job skill and knowledge and becomes a skilled worker. Throughout the Air Force, OJT is an essential and significant part of the integrated training program. It is a part of every unit's mission and requires the vigorous support of supervisors at all levels.

OJT is the primary method for training airmen to the skilled (5) level, and it is one of the two methods (OJT and resident school) for training them to the semiskilled (3) level. Advanced (7) level training may be accomplished entirely through OJT or through a combination of formal and on-the-job training.

As a trainer, you must be able to explain OJT program objectives in terms of both the Air Force mission and the position of the trainee. To do this, you must have a good understanding of the airman career program, particularly as it applies to your career field.

### 057. Explain the Air Force integrated training program in terms of personnel, types of training requirements, and responsibilities.

**Integrated Training Program.** The Air Force on-the-job training (OJT) program provides training for Air Force enlisted personnel to qualify them in the knowledge and job proficiency required to perform duty in an Air Force specialty (AFS). All Air Force organizations with assigned enlisted personnel conduct OJT.

*Relationship between formal training and OJT.* Air Force airmen technical training requirements are met by an integrated program involving all Air Force commands and some schools of the Army, Navy, and other Government agencies. The Air Force conducts a continuous and aggressive OJT program as a part of its integrated training program. Headquarters USAF, Director of Personnel Programs establishes training policies to ensure that OJT is integrated with all other elements of training. The Air Force Manpower and Personnel Center (AFMPC), Training Management Division provides overall management for the OJT Program. The Air Force recognizes that there are three specific requirements that airmen must satisfy to qualify for skill level upgrading. These requirements are career knowledge, job proficiency, and job experience. The Air Force dual channel OJT program is designed to satisfy the requirements for career knowledge and job proficiency. The requirement for job experience is satisfied when airmen satisfactorily perform duty in their AFS for the minimum time specified in AFR 35—1, *Military Personnel Classification Policy (Officers, Warrant Officers, Airmen).*

*Formal training.* Formal Air Force training includes training conducted both in approved courses and on the job. Air Training Command (ATC), in coordination with major commands (MAJCOMs), determines the requirements for, prepares, evaluates, and revises specialty training standards (STSs). These standards specify the amount of knowledge and skill required for training. They are the primary control documents for formal resident courses, career development courses (CDCs), OJT job proficiency guides, (JPGs), and specialty knowledge tests (SKTs). CDCs are used in conjunction with job proficiency training in the Air Force Dual-Channel OJT Program and as the primary reference for most SKT questions. The Extension Course Institute (ECI) publishes and administers CDCs.

Each MAJCOM must plan, conduct, and evaluate OJT according to regulation through practical application of the Dual-Channel OJT Program. In this text, references to the Dual-Channel OJT Program apply to that part of the Air Force training that conforms to the definition of OJT.

*On-The-Job Training.* On-the-job training is a planned training program designed to qualify airmen, through self-study and supervised instruction, to perform in a given AFS while actually working in a duty assignment of their AFS.

**Exercises (057):**

1. Which Air Force organizations must conduct on-the-job training?

2. Why must an organization conduct OJT?

3. What organizations are involved in meeting airman technical training requirements?

4. What organization insures that OJT is integrated with all other elements of training?

5. In addition to career knowledge training, what other requirements must an airman satisfy to qualify for upgrading?

6. The STS is the primary control document for what training and tests?

7. Is OJT formal or informal training?

8. What is the responsibility of each major command toward the OJT program?

9. Define "OJT."

10. What is formal Air Force training?

**058. Describe the Dual-Channel OJT Program in terms of purpose, where and how it is conducted, and the role of the JPG.**

**Dual-Channel OJT.** The Dual-Channel OJT Program is based The Dual Channel OJT Program is based upon the idea that there is, in career development, certain knowledge that airmen must gain if they are to move forward in the career field and if they are to have the ability needed to move quickly from one kind of equipment or system to another, or from one job to another. This knowledge is kin to, and concerned with, basic principles and theories. It is also involved with developing job proficiency by applying career area knowledge and by performing tasks related to a specific job assignment.

Dual-channel OJT is a systematic, reportable application of self-study and the craftsman-apprentice principle. Trainees acquire AFS knowledge by enrolling in and studying CDCs, when available, or by studying the study/technical references listed in the appropriate STS if CDCs are not available. Trainees gain job proficiency while performing on the job under supervision. This combination enables the airmen, upon reassignment, to perform, after a period of qualification training, the duties to which they are assigned in another unit.

OJT is conducted in the actual work situation by designated personnel who are working in support of the unit mission. Even though the responsibility for conducting OJT is delegated to specific individuals, the overall OJT program is of concern to every person assigned to the unit.

OJT is an integral part of every unit's mission. It requires vigorous support of commanders and supervisors at all levels. To be effective, an OJT program requires comprehensive planning, careful scheduling, timely implementation, capable direction, skillful application, and searching evaluation. As stated earlier, there are two distinct parts of the Dual-Channel OJT Program—knowledge and job proficiency development—which must be interpreted as career knowledge training and job proficiency training.

Career knowledge training is administered under one of two methods, depending on the availability of CDCs. Use of the CDC is mandatory if CDCs are available. If a CDC is not available, use the STS study/technical references (S/TRs) to satisfy the knowledge requirement for award of the appropriate skill-level AFSC. If neither a CDC nor STS is available, command and local JPGs will outline specific knowledge requirements.

The job knowledge training part of the Dual-Channel OJT Program is graphically depicted in Figure 3-7. The following paragraphs describe the other half of the Dual-Channel OJT Program—the job proficiency training phase, also shown in Figure 3-7.

Immediate supervisors are responsible for the development, maintenance, and effective use of JPGs. JPGs are used to assist in developing the trainee's job proficiency. The JPG provides airmen with specific reference to an authoritative publication for each task in their current duty assignments. As ATC revises STSs, specific references— including chapter and section number of TOs and other references are added. This procedure eliminates a great deal of unnecessary reading.

Air Force jobs require various combinations and degrees of skill and knowledge. Some are highly complex and require lengthy training periods; others are less complex and require correspondingly less training. Most of the training for the less complex jobs is conducted at unit level through OJT programs which include self-study and job proficiency training. For the more complex jobs, the ratio of the knowledge-to-skill requirements of the particular job determines the kind of training for an individual selected for that job.

For some complex AFSs, primary consideration must be given to the knowledge requirements. Since knowledge is most readily acquired in the classroom, it follows that most airmen who are selected for training into such jobs receive their initial training in formal technical schools.

In other types of complex jobs, the greater emphasis must be placed on the requirements for skill; therefore, supervised training on the job is often the most practical way of producing competent personnel. A 3- or 5-skill-level CDC provides the necessary career area knowledge for the OJT trainee.

After airmen have recieved appropriate initial job knowledge training, either in a formal school or on the job, the airmen still have to become thoroughly proficient in a duty position of the specialty for which they were trained. A formal school situation obviously does not lend itself to proficiency training. For individuals to become thoroughly skilled in the duty position, they must become semiskilled as a result of either a formal school or on-the-job training. They must receive additional training on the job to become fully skilled workers.

Since the entire OJT program hinges upon the learn-by-doing and self-study concepts, it follows that the part of the Dual-Channel OJT Program called job proficiency training is normally conducted within the unit to which the airman is assigned for duty. The responsibility for conducting the job proficiency phase of OJT is inherent in the job of each person, including civilians, who supervise the work of airmen. The responsibility for the career knowledge training part of OJT through self-study courses rests with the individual concerned. This training is monitored by the

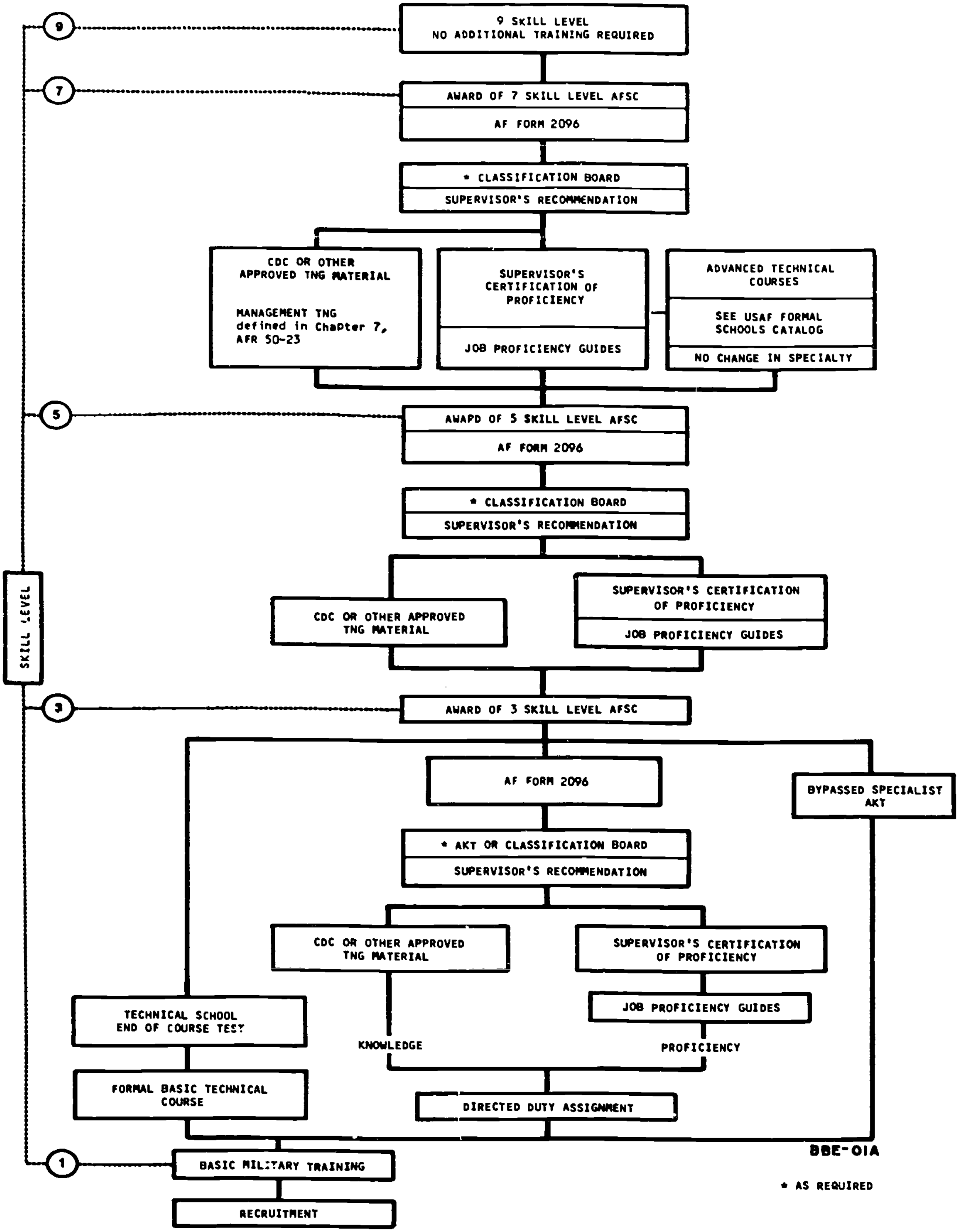


Figure 3–7. Skill progression.

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airman's immediate supervisor and the squadron OJT manager.

Job proficiency training implies practical application. It is that part of formal OJT which teaches skill. It places trainees in operational situations where they are assigned certain tasks which are part of their duty assignment. As trainees acquire skills in the simpler tasks, they are assigned others which are progressively more complex. In this way, trainees are constantly broadening their skills and knowledge, ultimately to include all elements of the job.

Learning in a job proficiency situation results from the close association between the trainee and the trainer. Understand, however, that this coach-pupil method of training does not preclude short periods of informational group instruction on job proficiency training elements.

**Exercises (058):**

1. What is the purpose of the dual-channel OJT program?

2. Where is on-the-job training conducted?

3. By what method(s) is OJT conducted?

4. What is OJT an integral part of?

5. How is the JPG used in OJT?

6. What determines the tasks an airman performs in OJT?

7. Who is responsible for identifying tasks an airman must perform during OJT?

8. If airmen need a specific reference on how to perform a task, where can they find it?

**059. Define the different types of training and relate them to OJT.**

OJT and UGT. On-the-job training is an all-inclusive term which describes the training received by an airman while he or she is performing in a duty assignment of the AFS. Training for the purpose of upgrading an airman's skill level in his or her AFSC is referred to as upgrade training (UGT). Training administered for the purpose of increasing knowledge and skill in an awarded AFSC, but not resulting in award of an AFSC, is referred to as qualification training.

**Qualification Training.** A program of qualification training designed to develop more knowledge and skill within an airman's assigned position is a basic part of the OJT program, but it does not result in the award of an AFSC. Qualification training does not require the use of special orders; AF Form 2095, Assignment/Personnel Action; AF Form 2096, Classification/On-The-Job Training Action; c but it does require entries on the JPG. Qualification training provides additional training for airmen who have already been upgraded in their specialties. It provides a practical application of the commander's awareness of the need for gearing the capabilities of the unit to changing Air Force concepts, requirements, equipment, and unit missions as well as recognizing that there is always a need for increased skill and knowledge within the broad confines of each skill level. Qualification training becomes critical when the commander is faced with the need for increasing the quality or amount of production, indoctrinating personnel in new techniques or procedures, or qualifying technicians to maintain new equipment.

Proper application of qualification training provides additional valuable experiences for all airmen who have been upgraded in their specialties to the 5- or 7-skill level.

**Retraining Programs.** Retraining through OJT is defined in AFR 39–4, *Airman Retraining Program*. It is designed to qualify an airman for award of an AFS or AFS shredout not in the normal progression pattern of a currently awarded AFS.

**Lateral Training.** Lateral training is accomplished in an AFS where the designated input is from another AFS. Lateral training, a planned part of the normal progression for certain AFSs, is shown in the career field charts of AFR 39–1, *Airman Classification Regulation*. Lateral Training may be given either through formal courses conducted by ATC or through OJT programs conducted at the unit level. When lateral training is given on the job, it is subject to the same controls as other OJT programs.

**Exercises (059):**

1. Define the following types of training:
   a. Upgrade training.

   b. Qualification training.

   c. Retraining.

2. How is qualification training conducted?

3. Why is there a need for qualification training?

4. In retraining through OJT, must an airman complete career knowledge training?

5. Explain your answer to item number 4.

6. If an airman is trained to the required proficiency level for every task listed in his JPG, does he need qualification training? Explain your answer.

7. What is the controlling publication used for:
   a. Lateral training?

   b. Retraining?

**060. Associate responsibilities for the OJT program with the person to which the responsibility is assigned.**

**Immediate Supervisor.** Responsibility for conducting OJT is inherent in the position of all supervisors. Since the supervisor (military or civilian) has daily contact with all the personnel assigned to the unit, the supervisor occupies a key position in the OJT program. In smaller sections, the immediate supervisor may also be the trainer. In any case, the title, immediate supervisor, is applicable to that person who maintains OJT records and forms and is responsible for those duties and responsibilities.

**Selection of OJT Trainers.** Ideally, the OJT trainer is the trainee's immediate supervisor. However, for various reasons this may be difficult to arrange in some organizations. As a result, trainers may be appointed to provide training for individuals or small groups of trainees. Appoint trainers who have broad fundamental knowledge and technical know-how, as well as the ability to get along with people and inspire the confidence of the trainees. The trainer is not to be thought of as an individual assigned to full-time instructional duty, but rather a skilled worker who is assigned to a production job.

**Relationship of Trainer to Trainee.** The on-the-job trainee needs motivation. Motivation stems from a felt need. The trainees should feel the need for OJT when the immediate supervisor accomplishes the requirements of AF Form 623, Section II, On-The-Job Training Record. The trainees must understand the need, the objectives, and the procedures of OJT, as well as their responsibilities to accept and perform training assignments to the best of their abilities. The supervisor or trainer has to adapt orientation procedures to each situation to make clear to the trainees their responsibilities as presented in Chapter 4 of AFR 50—23.

**Exercises (060):**

1. Match the responsibility for the OJT program in column B with the assigned person in column A by writing the appropriate letter in the blank. (All persons have three or more responsibilities listed.)

| *Column A* | *Column B* |
|---|---|
| _____ (1) Immediate supervisor. | a. Maintains all issued training materials in good condition for future use. |
| _____ (2) OJT trainer. | b. Maintains AF Form 623 for assigned airmen. |
| _____ (3) OJT trainee. | c. Instructs trainee on actual equipment. |
| | d. When reassigned, obtains and delivers appropriate CDC materials to new unit OJT manager. |
| | e. Teaches theory and background information when required. |
| | f. Indoctrinates trainers and trainees on objectives of the OJT program. |
| | g. Motivates and evaluates assigned training. |
| | h. Certifies completion of job proficiency training. |
| | i. Accepts and performs all training requirements and assignments in an efficient manner. |
| | j. Using the duty section Master Job Proficiency Guide, develops the JPG as a basic document for training, based on the airman's duty position. |

**061. Identify selected training principles and methods, and compare OJT techniques with formal training techniques.**

**Training Principles.** Certain basic and easily understood principles apply to all training situations. Trainers should understand and apply the principles outlined below. These principles will help trainers to improve their skill in instructing.

*a.* Go from the known to the unknown. Find out what the trainees know about the subject and build from there. Relate the new material to previously learned subjects. Give trainees a complete briefing on the overall program and tell them where they fit into it. Acquaint them with the goal. Make sure the part they play in the organization is understood and make them aware that they are vital members of the team.

*b.* Go from the easy to the difficult. Always begin with the simple parts of a job. The knowledge that they are able to perform parts of the job after a practice period gives the trainees confidence and inspiration to learn the whole job.

*c.* Emphasize accuracy and understanding rather than speed. while the trainee is learning.

*d.* Emphasize safety at all times.

*e*. Clearly define the limits of the training objective and let the trainees know what is expected.

*f*. Present new material in short units that can be finished in one training session. Short, related training units are not so likely to confuse the trainees.

*g*. Be sure the trainees see the job as a whole. Fit all the short steps into the whole operation or objective.

*h*. Always remember that the trainees learn by doing. Put them to work as soon as they understand what they are to do. Give them plenty of practice.

*i*. Allow trainees to develop. They do the learning; you guide and help. Be careful not to dominate, but do not relax your supervision to a point that would allow the trainees to harm themselves, others, or damage equipment.

*j*. Any training procedure must make sense to the trainees. If it doesn't, change or discard it.

*k*. Recognize the trainees' work. Let them know how they're doing.

*l*. Never try to bluff. Never resort to sarcasm or ridicule.

**Training Methods.** An OJT trainer must assume trainer responsibility, in addition to other duties; the OJT trainer function is not considered a full time duty. Supervisors may sometimes be required to perform as trainers. OJT trainers are expected to use effective training methods and techniques. This requirement and responsibility is contained in the specialty description of all skilled and advanced level AFSs. It follows that those who are selected as trainers must learn to perform efficiently, using methods that result in an effective OJT program. Job instruction generally involves four methods of imparting new knowledge or manual skills.

*The lecture*. The lecture is useful for imparting information. Its effectiveness is increased when it is combined with one or more of the other instructional methods.

*The discussion*. The discussion is a valuable training method because it promotes a two-way exchange of ideas during group instruction, when the objective is to provide background information or procedures that are of common interest to the entire group. Questioning is very useful when employing the discussion method to inform the trainees, as well as to check their grasp of the instruction. To help the trainee think through the logical steps of a new job task, phrase your questions so that they can't be answered with a straight yes or no. Use questions that begin with such words as what, who, here, when, why, and how. Questioning can be used effectively with all other instructional methods, as well as with the discussion method.

*The demonstration*. The demonstration or showing is most effective when the training objective is the development of new manual skills. It is particularly useful in presenting the various steps of a very long operation that must be performed without stopping. The trainees are taught a part of the job, with the trainer doing the rest. After learning one step of the total job, the second step is taught, with the trainer again completing the operation.

*The performance*. The performance is by far the most effective method to use in OJT. Trainees truly learn by doing under the watchful eye of a trainer while performing in a productive capacity. It follows that airmen on OJT should immediately be given simple jobs to do, such as cleaning or sorting parts, counting pieces, sorting papers, learning names of parts, or checking supplies. It is most practical to assign such airmen to assist others who are producing. After airmen have received training on some particular task or phase of work, they are able to do it with the desired proficiency. They should then be rotated to another task. With a progressive rotation plan, trainees grow in skill and knowledge until they are able to accomplish effectively the requirements of the duty position.

**Training Techniques.** Supervisors must make sure that trainers develop a set of techniques similar to the five steps which follow so that all OJT can be effectively conducted.

*Step 1*. Prepare the training situation.

*a*. Make sure that the tools and equipment are on hand and in working order.

*b*. See that the shop or room is available and that it is properly heated, lighted, and ventilated.

*c*. See that training aids planned for use are available and in good working order.

*Step 2*. Prepare the trainees to receive job instruction.

*a*. Put them at ease. This helps build confidence. The supervisor's training efforts are likely to be in vain if trainees are nervous or ill at ease.

*b*. Find out what they already know about the job. Don't tell them things that they already know. Start where their knowledge ends.

*c*. Gain their interest. Explain the job or operation at hand and relate that job to the work of the whole unit. This helps them realize the importance of the job.

*d*. When demonstrating a job, make sure the trainees observe from the proper position. Don't have them look backwards or from an angle other than the one from which they will work.

*Step 3*. Present the operation.

*a*. Tell, show, illustrate, and then question. Once understanding is achieved, have the trainees perform the task.

*b*. Give only a few instructions at one time. Understanding is gained more quickly if ideas are presented gradually.

*c*. Make the key points clear. These make or break the operation; to a large extent, they determine the ultimate success or failure of the training.

*d*. Use available training aids when they help to put the point across. Don't use them just to fill in time. Before using any training aid, be sure that it applies directly to the subject and that it works.

*e*. Be patient; remember that haste makes waste. Work for accuracy first, speed later.

*f*. Repeat the job and explanation, if necessary.

*Step 4*. Try-out performance.

*a*. Have the trainees do the job under observation. Then repeat the job and have them explain what they are doing, and why. Some people don't realize the importance of motions they are observing and repeating. The trainees must understand not only what, but why.

*b*. Have the trainees explain the key points. Correct any errors, but do not correct in a way which will make them feel that you are not satisfied with their progress.

*c*. Continue to have the trainees perform and explain until you know that they understand what they are doing.

*Step 5*. Followup.

*a*. Put the trainees on their own so they will get the feel of the job by doing it. Tell them who they should go to for help, and make sure the designated individuals understand their responsibility.

*b*. Check trainees' work frequently—perhaps every few minutes at the start, then every few hours. Be on the lookout for incorrect or unnecessary moves, but don't make an issue over them. Expect a few mistakes; if there are none, congratulate the trainees for a job well done.

*c*. Taper off the coaching until the trainees are able to work under normal supervision. Be sure that the trainees are adhering to the approved safety practices. Safety is one of every supervisor's most important responsibilities. Make it clear, both by instruction and attitude, that, strictly speaking, accidents don't just happen—they are provoked. The cause of an accident may not always be readily apparent, but it can usually be found. Common causes include lack of skill, poor work habits, poor attitudes, and/or faulty instructions. If you discover that trainees are having more than their share of accidents, and if you have eliminated faulty instruction as a possible cause, report the fact to your supervisor for action.

**Exercises (061):**

1. Match the principle in column B with the definitions or situations in column A by entering the proper letter in the space provided.

*Column A*

_____ (1) The trainer patiently explains a performance step to a trainee for the third time.
_____ (2) A trainer stops a trainee from turning on a switch that should be OFF during maintenance.
_____ (3) The trainer tells trainee what the end product will be.
_____ (4) A trainer starts the instruction on how to do a simple task.
_____ (5) The trainer explains where the trainee fits in the organization.
_____ (6) Trainees are warned of high noise levels and shown how to insert earplugs.
_____ (7) Let trainee do task with only an occasional check after you know trainee can do it.
_____ (8) Trainer praises good work habits used by trainee.
_____ (9) Let trainee do task as soon as you know it is understood.
_____ (10) The trainer compares operation of a centrifugal pump to a rotary lawn mower.
_____ (11) Trainee can do a complete operation at end of each training session.
_____ (12) After trainer explains an operation, trainee is asked to explain it.
_____ (13) Trainer explains what trainee should be able to do at end of training period.
_____ (14) Have trainee do task several times while trainer watches.

*Column B*

a. Go from the known to the unknown.
b. Go from the easy to the difficult.
c. Emphasize accuracy and understanding.
d. Emphasize safety.
e. Define limits of the training objective.
f. Trainer learns by doing.
g. Recognize the trainee's work.
h. Present new material in short units.
i. Allow the trainee to develop.
j. Let trainee see job as a whole.

2. The lecture method is useful for teaching information, but why is the performance method of instruction the most effective to use in OJT?

3. Why should a combination of teaching methods probably be useful with new trainees?

4. How do the training techniques compare with the techniques used in a formal training course? (Compare OJT trainer activities to classroom instructor activities—step by step.)

**062. Identify the purpose of, and the responsibilities for, the task breakdown, and give selected techniques for "breaking down" a task.**

As the instructor breaks down the objectives into segments for the lesson plan, so should the trainer break down tasks into teachable segments.

**Task Breakdowns.** Specialty training standards break down an AFS into various individual tasks and knowledges. These tasks and knowledges are required for each specialty within the ladder to indicate the extent of knowledge or degree of proficiency required for each skill level. However, many of the individual tasks and items are in themselves quite complex. The OJT trainer must break these down into a logical, systematic sequence of parts and teach each part as a complete unit. These written breakdowns of complex tasks or operations are known simply as task breakdowns.

*Purpose of the task breakdown*. Many OJT trainers may think they know a task when they really don't. Others may know the task so well that they neglect to clarify a point which is simple to them but confusing to the trainee. Still others may know the task so well that they do not plan how to teach it to another person.

For some tasks, the breakdown may be as simple as saying to the trainee, "Do this first, this next, and then do that." However, many Air Force jobs are extremely complex. Complete performance of such jobs is overwhelming to the young and inexperienced airman.

The purpose of the task breakdown is to divide the big job into easy, progressive, and teachable units. This makes it possible for the airman to learn the job in small doses, one step at a time.

The degree of which a task must be broken down depends on the past experience and learning capability of the trainee. The trainer must determine when the task is broken down far enough to be easily taught and readily understood.

*Format of the task breakdown*. As a management device, the task breakdown consists essentially of two columns. One is titled "Important steps" and the other is titled "Key Points."

(1) Important steps. The steps are logical segments of the operation which advance the work. These breakdowns are not intended to be hairsplitting; ratner, they are to be simple, common sense reminders of what is really important in doing a task.

(2) Key Points. Knowing what the key points are and how to pick them out quickly and easily is an important part of job instruction. They are:

- Hazards which may cause injury to personnel or damage to tools and equipment.
- Things which make or break the task.
- Things which make the work easier—knack, trick, feel, and special timing.

*Preparation of the task breakdown*. There are several procedures by which trainers may prepare task breakdowns. Their own experience and the type of task to be performed determine which procedure to follow.

Some tasks may be so well understood that they can be analyzed and divided into simple, logical steps, just by thinking through the various stages of the operation. Others may be too complex to break down without going through the entire operation and making notes on the performance of each part.

Sometimes trainers may have to break down a task in which they've had little personal experience. If so, they should carefully watch the motions and steps used by someone more expert in the task.

In each case, the objective is to find how the trainer can best help the trainee to perform each operation safely, easily, correctly, and quickly. This involves the knacks, tricks of the trade, special timing, key points, and special information on what to look for, where to look, how to feel, and what to listen for, in each operation.

Task breakdown sheets are not necessarily intended to be given to the trainee. They are for the trainer's use in clarifying and organizing their own thinking about the task. For this reason, it is not necessary to formalize them.

All tasks are identified in a general manner in JPGs. However, the task breakdown should be prepared personally by the on-the-job trainer. As with most other operations, task breakdowns can be made easily and quickly after a little practice.

Supervisors should arrange for group instructions, discussions, practice sessions, and critiques with trainers, to ensure proper preparation of task breakdowns.

**Exercises (062):**

1. Why must some tasks be broken down before you attempt to teach them?

2. State the purpose of the task breakdown.

3. The degree to which a task must be broken down depends upon what factors?

4. Give the two column headings that should be used in preparing a task breakdown.

5. What should be your objective in preparing a task breakdown?

6. Who is responsible for preparing the task breakdown?

7. Who must insure the proper preparation of a task breakdown?

**063. Cite the requirements for a training capability and the actions to take if the training capability is questionable or nonexistent.**

**Training Capability.** When planning your OJT program, find out if your unit has a training capability. You may assume that your unit or section has the capability to accomplish the prescribed OJT. But it is possible that local situations or temporary conditions may make realistic on-the-job training impractical or impossible. We will look at the question of training capability from three view points: when a training capability exists, when a training capability is questionable, and when a training capability does not exist.

*When a training capability exists*. In general, for a training capability to exist, there must be a CDC for the AFSC and/or the Specialty Training Standard/Study References (STS/SRs) and a person capable of administering job proficiency training. There are many misconceptions about the subject of training capability. The most prevalent one is the belief that the trainer must possess the same AFSC at the same or higher skill level in which the training is desired. Another belief is that to "certify" job proficiency, the person doing the certifying must be technically qualified to perform the function being

considered. There must be some individual to certify job proficiency.

For example, a supervisor ay certify job proficiency on a task if the performance can be observed and verified by a TO, manual, or other authoritative reference. Verification should assure that proper procedures, tools, materials, etc, are used and that the work, when completed, conforms to established standards.

*When a training capability is questionable*. If the presence of training capability is questionable, all factors must be carefully weighed by a competent authority (appointed by the Chief, Personnel Division) possessing all the facts. The Chief, Personnel Division, recommends approval of entry into training if there is a training capability.

*When a training capability does not exist*. If it is determined that a training capability does not exist, the Chief, Personnel Division, forwards a statement of the circumstances to MAJCOMs command. In these instances, major take action to provide a training capability.

We can say then, that for a training capability to exist we need a CDC and/or STS/SR for that AFSC, and an individual to conduct job proficiency training.

**Exercises (063):**

1. For a training capability to exist for the career knowledge channel of OJT, what must be available?

2. For a training capability to exist for the job proficiency channel of OJT, what must be available?

3. Briefly explain how a supervisor can "certify" job proficiency on a task if the AFSCs of the trainer and trainee are not the same.

4. What does verification of proficiency mean?

5. If a training capability is questionable, what action must be taken?

6. If a training capability does not exist, what must be done?

7. If a training capability does not exist, what level of command is responsible for providing the capability?

**064. State the process of evaluating and recommending personnel for training.**

**Evaluating and Recommending Personnel for Training.** We have covered a number of training programs thus far, and you should have a good understanding of how the Air Force training program works. Let's put this newly acquired knowledge to practical use.

Every supervisor has learned that a well trained group of workers plays a big part in meeting the unit's mission. The same elements that affect the accomplishment of the overall Air Force mission—i.e., technological advancements, personnel changes, and career field adjustments—affect your unit's mission. It would be great if we always had the same people and our jobs always remained the same. We wouldn't have to worry about training. But it just doesn't work that way. You receive new people in your shop from time to time, and your trained workers are transferred out. Equipment, procedures, and methods change, and your unit's mission may change.

To maintain an effective unit, the people who work for you require training. The questions that each supervisor must ask are: "How many need training?" and "What type of training is required to meet my unit's mission?" Therefore, the main problem you face is to find out the needs of each individual. By doing this you can make recommendations for the type of training that each person needs. This may be accomplished by applying a plan of evaluation.

During the evaluation process, you should identify both the current and projected training requirements of each employee. This evaluation is made on the basis of several determinations.

First, you must determine what work needs to be done and the specific things your people must do if they are to work effectively. There are a number of sources where you can get information concerning the work to be done. These sources include the specialty description, STS, JPG and job breakdown, and the job performance requirements.

Second, you need to find out what your workers can do at the present time. There are a few ways that you can do this. We can usually get records that show background, training, and experience of the trainee. Take time out to talk to each person individually. This will show your interest in them, while, at the same time, they will be much more receptive to the training program. We can also evaluate, or rate them on the job by asking them to demonstrate their skills with certain pieces of equipment or tasks. Simple observations of your worker's methods and work habits may show the need for more training.

Third, let's keep in mind that each person is an individual. Every person differs in skill, aptitude, and qualifications. Not all workers have the same abilities to learn various jobs.

Once you have gathered the information on each employee, it is a matter of comparing the qualifications and abilities of the employee to the requirements of the job assignment. From this information you can recommend the type and amount of training he or she needs to do the job.

**Exercises (064):**

1. List three elements that could affect your unit's mission.

2. How can you find out what the training needs are of each individual in your shop?

3. What two items should you identify when evaluating a training plan?

4. N e the sources you can use to determine what work needs to be done.

**065. State how the effectiveness of a training program is evaluated.**

**Effectiveness of a Training Program.** The effectiveness of your training program depends on how seriously your people accept their responsibilities to the total training program. Everyone, from MAJCOM to the trainee, must do his or her part to make the program work. One of the best things that you can do to insure an effective program is to check how well the trainer has trained the trainee. If you make sure that the following checklist of items is being met to its fullest extent, then you will have an effective program in your shop.

*Pretraining preparation.* You and the trainer should make sure that everything you need is available. This includes:

*a.* A current STS.

*b.* A JPG based on what the trainees are expected to do in their current job.

*c.* A task breakdown for each task that the trainees are to do.

*d.* All the supplies, tools, and equipment to do each task. These tools and equipment should be in proper working order.

*Motivation.* It is part of your job to make sure that the trainee is motivated to learn. An occasional, inconspicuous, observation on your part will quickly tell you if your people are motivated.

*Knowledge of the job.* Most of the time you can tell how well people know their jobs by the ease and confidence with which they perform. You should keep this in mind when you assign your trainers.

*Trainee participation.* This is one of the most important parts of the training program. Without the participation of the trainees, all other efforts may be for naught. On the other hand, if your trainees show sustained activity and performance throughout job performance, you can pretty well assure yourself that your training efforts will meet your assigned mission.

*Evaluation techniques.* In any course of study or training program, the students must be evaluated (tested) to see if they have learned what was taught. The method of evaluation must be consistent with the subject that was taught. Subject and task knowledge are measured by written tests; skill and physical abilities are measured by actual performance. In other words, you can't evaluate your trainees' ability to work the controls of a bucket truck by giving them a written test. You should give them a performance type test so you can evaluate their skills.

*Equipment utilization.* During OJT, trainees may have become experts on the use of a piece of equipment, but unless they exercise all of the applicable safety factors, one could not truthfully say that the training has been completely effective. Broken equipment is of no use. Worse yet, personal injury or death could result if safety procedures are not observed. All the expert knowledge in the world is of no good use unless safety is observed in every part of the job.

When following these suggestions to evaluate your training program, be sure to document all observations. You should write down all of the strong points, as well as the weak ones. Also, write down any suggestions that you feel would improve your training program. These notes will help you in later evaluations.

**Exercises (065):**

1. On what does the effectiveness of a training program depend?

2. List four things that should be available before you start training.

3. What is the most important part of the training program?

4. You are teaching Sgt. Fred Jones the theory of transformer operation, which method, written or performance, would be the best method to evaluate what he learned from it?

5. You are teaching Airman Ellen Day to make transformer connections, which method, written or performance, would be the best method to evaluate what she learned from it?

**066. State reasons for participation in the USAF Graduate Evaluation Program.**

In addition to evaluating the people who work for you, you may, from time to time, be required to evaluate the effectiveness of training received from formal courses and CDCs.

**Field Evaluation Program.** From time, to time airmen who have graduated from technical schools will be assigned to your shop. In addition, people from your shop may attend advanced or special courses. Most certainly, personnel in your shop will be completing CDCs as they advance their Air Force careers. The field evaluation program is set up to aid in the quality control of these courses. This program is a source of information used to determine the following:

*a.* Ability of recent graduates to perform their assigned tasks to the level of proficienc specified in the applicable training standard.

*b.* Extent to which acquired skills are used by recent graduates.

*c.* Extent to which knowledge attained is retained by recent graduates.

*d.* Need to revise the approved STS /n STS, formal courses or CDCs in order to improve training.

*e.* Need for further evaluation of training problem areas identified by this evaluation of graduates.

Your participation in the field evaluation program could help improve CDCs and formal courses.

**Exercises (066):**

1. What types of training do you evaluate in the field evaluation program?

2. List five reasons why your participation is needed in the field evaluation program.

**067. Define the Specialty Training Standard (STS) and specify the contents of page 1.**

**Air Force Specialty Training Standards.** Specialty training standards are Department of the Air Force (DAF) publications. The STS is the official Air Force specification for training. It lists the skills and knowledge that airmen in a specialty need to perform on the job.

The knowledge that airmen are required to have and the tasks they are required to do are based upon the Air Force Specialty Description and are used in preparing the STSs. This means that if an airman must use a typewriter on his or her job, the knowledge and tasks required to operate a typewriter are included in the STS for the Air Force Specialty. A system of code letters or number/letter combinations is used in the STS to indicate the extent to which the individual should be trained in each knowledge and task to qualify for upgrading to a specific skill level. This, in turn, determines the extent to which formal courses and OJT programs provide training on each of the listed knowledge and tasks.

The knowledge and tasks for a particular STS are obtained from three main sources. One of these sources is the official Specialty Description, published in AFR 39–1. The STSs correlate with and expand the AFS descriptions contained in AFR 39—1. Another source is the comments or recommendations from the MAJCOMs who use personnel in the particular specialty. The third source is the Specialty Survey Reports. These are products of AFR 35–2, *Occupational Analysis*.

The STS serves two main purposes: (1) as a control for on-the-job training and (2) as a control of training within a course. The first page of an STS is shown in figure 3-8. Note that it contains information under these five headings:

(1) Purpose of this Specialty Training Standard (STS).

(2) Proficiency Code Key.

(3) Career Development Channel of OJT.

(4) Study Guidance for Weighted Airman Promotion System (WAPS).

(5) Recommendations.

Take time to study the information under each heading in figure 3-8. The information is standard on all STS. In general, the information explains the preparation, use, and interpretation of the STS.

**Exercises (067):**

1. What is an STS?

2. What are the contents of column 1 in the qualitative requirement, of attachment 1 of the STS?

3. What skill levels are listed in the STS?

4. What does paragraph 3 of page 1 of the STS explain?

**068. Define given a list of the scale values for task performance, task knowledge, subject knowledge, and other STS codes, correlate each to its meaning.**

**Proficiency Code Key.** Page 2 of the STS is the beginning of attachment 1. It contains space for identifying the OJT trainee and supervisor and the proficiency code key used to explain proficiency levels. Note in figure 3-9 that the key is divided into three sections. The first section deals with the task performance levels. The value of performance is indicated in Arabic numerals, 1 through 4. Each Arabic scale value is followed by its definition, indicating how well airmen must perform the designated task on the job. If there is a formal course for that skill level, the definition

# SAMPLE STS

DEPARTMENT OF THE AIR FORCE
Headquarters, US Air Force
Washington DC 20330

STS 542X0
(For AFSCs 54230/50/70)
August 1978

DATE IS ESTABLISHED BY HQ ATC APPROVER AND TYPED WITHIN ATC/TTSS.

## ELECTRICIAN AND ELECTRICAL TECHNICIAN

1. Purpose of this Specialty Training Standard (STS). As prescribed in AFR 8-13, this STS:

a. States in column 1 of attachment 1 the tasks, knowledge, and study references (SR) necessary for airmen to perform duties in the Electrician ladder of the Airman Civil Engineering Mechanical/Electrical Career Field. These are based on Specialty Descriptions in AFR 39-1.

b. Indicates in columns 2A, 3A, and 4A of attachment 1 the minimum proficiency recommended for each task or knowledge for qualification at the 3, 5, and 7-skill level AFSCs. AFM 50-23 contains authority to change the proficiency level during JPG development when the local requirement is different from the level shown in this STS.

c. Shows in column 2A of attachment 1 the proficiency attained in Course J3ABR54230 001 (PDS Code AJZ), described in AFM 50-5. Proficiency code for the minimum proficiency recommended for the 3-skill level AFSC and the proficiency attained in the course is the same except when dual codes are entered. When dual codes are entered, the second code shows the proficiency attained in the course.

d. Provides basis for supervisors to plan and conduct individual OJT programs.

e. Provides a convenient record of on-the-job training completed when inserted in AF Form 623, "On-the-Job Training Record," and maintained in accordance with AFM 50-23. Previous editions of this STS may be used in accordance with AFM 50-23, paragraph 6-5.

f. Defines the knowledge requirements covered by Specialty Knowledge Tests in the Weighted Airman Promotion System.

2. Proficiency Code Key. Attachment 1 contains the proficiency code key used to show proficiency level.

3. Career Development Channel of OJT. Satisfactory completion of CDC 54230 is mandatory for personnel training to AFSC 54230. Satisfactory completion of CDC 5421i is mandatory for personnel training to AFSC 54250. Personnel training to AFSC 54270 will obtain knowledge training by using applicable study references listed in this STS, and fulfill management training requirements specified in AFM 50-23. (See ECI Catalog and Guide, chapter 6, for current CDC identification number for ordering purposes.)

4. Study Guidance for Weighted Airman Promotion System (WAPS). Specialty Knowledge Tests (SKT) for promotion to E-5 are based on 5-skill level knowledge requirements. SKTs for promotion to E-6 and E-7 are based on 7-skill level knowledge requirements. SKT questions are based primarily on Career Development Courses (CDC). If the SKT is also based on some other references listed in this STS, the specific SKT study references are listed in AFP 39-8. The CDCs for SKT study are maintained in the WAPS study reference library. Study references listed in AFP 39-8 should be available in the work area. Individual responsibilities are contained in AFR 35-8, chapter 14, paragraph 14-3h.

5. Recommendations. Report to ATC/TT unsatisfactory performance of individual graduates or inadequacies of this STS. Refer to specific paragraphs of this STS. See AFR 50-38.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

OFFICIAL

LEW ALLEN JR, General, USAF
Chief of Staff

JAMES J. SHEPPARD, Colonel, USAF
Director of Administration

1 Attachment
Qualitative Requirements

Supersedes STS 542X0, 2 December 1970; Change 1, 14 January 1972; Change 2, 6 March 1973; Change 3, 18 April 1973; Change 4, 25 February 1974; Change 5, 7 November 1974; Change 6, 1 May 1975; and Change 7, 12 February 1976.

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Figure 3–8. Page 1, Specialty Training Standard (STS).

STS (NUMBER)

| THIS BLOCK IS FOR IDENTIFICATION PURPOSES ONLY | | |
|---|---|---|
| TRAINEE | | |
| NAME | INITIALS (In Writing) | GRADE |
| ORGANIZATION | | |
| TRAINER'S NAMES AND INITIALS (In Writing) | | |
| N/I | N/I | |
| N/I | N/I | |

## QUALITATIVE REQUIREMENTS

| PROFICIENCY CODE KEY | | |
|---|---|---|
| | SCALE VALUE | DEFINITION: The Individual |
| TASK PERFORMANCE LEVELS | 1 | Can do simple parts of the task. Needs to be told or shown how to do most of the task. (EXTREMELY LIMITED) |
| | 2 | Can do most parts of the task. Needs help only on hardest parts. May not meet local demands for speed or accuracy. (PARTIALLY PROFICIENT) |
| | 3 | Can do all parts of the task. Needs only a spot check of completed work. Meets minimum local demands for speed and accuracy. (COMPETENT) |
| | 4 | Can do the complete task quickly and accurately. Can tell or show others how to do the task. (HIGHLY PROFICIENT) |
| * TASK KNOWLEDGE LEVELS | a | Can name parts, tools, and simple facts about the task. (NOMENCLATURE) |
| | b | Can determine step by step procedures for doing the task. (PROCEDURES) |
| | c | Can explain why and when the task must be done and why each step is needed. (OPERATING PRINCIPLES) |
| | d | Can predict, identify, and resolve problems about the task. (COMPLETE THEORY) |
| ** SUBJECT KNOWLEDGE LEVELS | A | Can identify basic facts and terms about the subject. (FACTS) |
| | B | Can explain relationship of basic facts and state general principles about the subject. (PRINCIPLES) |
| | C | Can analyze facts and principles and draw conclusions about the subject. (ANALYSIS) |
| | D | Can evaluate conditions and make proper decisions about the subject. (EVALUATION) |

– EXPLANATIONS –

* A task knowledge scale value may be used alone or with a task performance scale value to define a level of knowledge for a specific task. (Examples: b and 1b)

** A subject knowledge scale value is used alone to define a level of knowledge for a subject not directly related to any specific task, or for a subject common to several tasks.

– This mark is used alone instead of a scale value to show that no proficiency training is provided in the course, or that no proficiency is required at this skill level.

X This mark is used alone in course columns to show that training is not given due to limitations in resources.

2 ATTACHMENT 1

BBE – 045

Figure 3–9. Proficiency code key.

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also indicates the training airmen should receive in the course. The second section of the proficiency code key is the task knowledge levels section. The value of the task knowledge is indicated by lower case letters *a* through *d*. Each task knowledge value letter is followed by its definition, showing the level of knowledge in performing the task that airmen need at a particular skill level. The third section deals with the subject knowledge, indicated by capital letters A through D and followed by their definitions. These are knowledges that do not relate to any one task but to the AFS as a whole. Airmen need these knowledges to perform in their specialty.

The codes are used to express the minimum proficiency to which airmen must be trained. For example, a task coded "2b" means that the training given on that task must enable students to "determine step-by-step procedures for doing the task" (see fig. 3-9). They must be able to "do most parts of the task." They will "need help only on the hardest parts." They "may not meet local demands for speed or accuracy." In short, they are PARTIALLY PROFICIENT.

Sometimes, there is a task in an STS for which no proficiency training is provided or for which no proficiency is required at that skill level. If so, the element is coded with a dash (—) (see bottom of fig. 3-9). Also, there are times when training (in a resident course) cannot be given because of limitations in resources, such as equipment or facilities. In this case, the task is coded with an "X."

When course graduates are assigned to a job in the field, this coding shows commanders, supervisors, and trainers the proficiency to which these graduates have been trained in the formal training course. A dash or an "X" informs supervisory personnel in the field that no training was given on that task. The same symbols are used to indicate the training the airman receives in OJT. If additional training is needed, the supervisor knows that it must be accomplished through on-the-job training or other formal training courses.

**Exercises (068):**

Match each of the following scale values and STS codes in column A with its meaning in column B. Write the letter of the meaning in the appropriate blank.

*Column A*

_____ 1. a.
_____ 2. b.
_____ 3. c.
_____ 4. d.
_____ 5. 1.
_____ 6. 2.
_____ 7. 3.
_____ 8. 4.
_____ 9. A.
_____ 10. B.
_____ 11. C.
_____ 12. D.
_____ 13. –.
_____ 14. X.

*Column B*

a. Can evaluate conditions and make proper decisions about the subject.
b. Can do all parts of the task. Needs only a spot check of the completed work.
c. Can explain why and when the task must be done and why each step is needed.
d. This mark used in course columns only. It indicates that training is not given on the task or knowledge statement in the course.
e. Can identify basic facts and terms about the subject.
f. Can do simple parts of the task. Needs to be told or shown how to do most of the task.
g. Can name parts, tools, and simple facts about the task.
h. Can analyze facts and principles and draw conclusions about the subject.
i. Can determine step-by-step procedures for doing the task.

*Column B*

j. Can do the complete task quickly and accurately. Can tell or show others how to do the task.
k. No proficiency is required at this skill level or no proficiency training provided in the course.
l. Can explain relationship of basic facts and state general principles about the subject.
m. Can predict, identify, and resolve problems about the task.
n. Can do most parts of the task. Needs help only on the hardest parts. May not meet local demands for speed or accuracy.

**069. Identify selected features of STS qualitative requirements.**

**STS Qualitative Requirements.** The remaining pages of the STS make up the qualitative requirements, which are the job tasks, knowledges, and proficiency level requirements. They are listed in a standard four-column format as shown in figure 3-10. 10. The entries in columns 1, 2A, and 4A pertain to the development of formal courses of instruction. OJT is based on the entries in columns 1, 2B, and C, 3B and C, and 4B and C.

Column 1 of the STS qualitative requirements contains each task or knowledge required by the AFS, regardless of whether the training is included in the USAF formal school course(s) or provided by OJT. For example, tasks are listed by duty, major equipment, or system. Knowledge statements are listed by major subject area. The task and knowledge statements entered in column 1 are based upon the Duties and Responsibilities section of the Specialty Description in AFR 39–1. Normally, no element in the Specialty Description is omitted, and no job task is included unless it is within the scope of the Specialty Description. The STS normally excludes knowledges and tasks worded to a specific system or job assignment. Such items are applicable to the job proficiency guide (JPG). In addition to the tasks and and knowledges, column 1 contains study/technical references that are directly related to and support specific task and knowledge training. These are especially significant in on-the-job training.

Columns 2, 3, and 4 contain information for the 3, 5, and 7 skill levels respectively. Each numbered column contains additional columns, identified by A, B, and C. The entries in columns 2A, 3A, and 4A indicate the minimum proficiency recommended for each task or knowledge for qualification at the 3-, 5-, and 7-skill-level AFSCs. The entries in columns 2A and 4A indicate whether or not Air Training Command (ATC) courses are available to aid in the individual's progression and the extent of such training needed for graduation from the course. If no course is available, the phrase "no basic course" or "no advanced course" is printed in column 2A and/or 4A. There are no 5-skill-level courses offered in most of the AFSs.

If a resident course cannot teach a task to the required proficiency level, the task may be coded "2b/1a" (see column 2A, fig 3-10). This indicates that the course teaches the task but to a lower level than required on the job. If this

| 1. TASKS, KNOWLEDGE AND STUDY REFERENCES | PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION: 2. 3 SKILL LEVEL | | | 3. 5 SKILL LEVEL | | | 4. 7 SKILL LEVEL | | |
|---|---|---|---|---|---|---|---|---|---|
| | A AFSC /Crs | B Date OJT Started | C Date Compld & Trainee's Supervisor's Initials | A AFSC | B Date OJT Started | C Date Compld & Trainee's Supervisor's Initials | A AFSC /Crs | B Date OJT Started | C Date Compld & Trainee's Supervisor's Initials |
| 10a. Interpret plans, sketches, wiring diagrams, and specifications | 2b | | | 3c | | | 4c | | |
| b. Calculate power requirements for electrical systems | - | | | 2b | | | 4c | | |
| c. Determine type and size of conductors, protective devices, and physical protection required for electrical systems | - | | | 2b | | | 4c | | |
| d. Plan sequence of work operations | - | | | 2b | | | 4c | | |
| e. Coordinate electrical work with other specialists | - | | | 2b | | | 4c | | |
| 11. INSTALLING INTERIOR DISTRIBUTION SYSTEMS, MOTORS, AND CONTROL CIRCUITS | | | | | | | | | |
| SR: AFMs 88-15, 91-17; National Electrical Code | | | | | | | | | |
| a. Install and connect | | | | | | | | | |
| (1) Service entrances | 2b/b | | | 3c | | | 4c | | |
| (2) Service equipment | 2b/b | | | 3c | | | 4c | | |
| (3) System and equipment grounds | 2b/b | | | 3c | | | 4c | NO ADVANCED COURSE | |
| (4) Feeders | 2b/b | | | 3c | | | 4c | | |
| (5) Distribution panels and protective devices | 2b | | | 3c | | | 4c | | |
| (6) Branch circuits | 2b | | | 3c | | | 4c | | |
| (7) Switches, receptacles and lighting fixtures | 2b | | | 3c | | | 4c | | |
| (8) Motors | 1a | | | 3c | | | 4c | | |
| (9) Motor control circuits | 1a | | | 3c | | | 4c | | |
| (10) Electrical systems in hazardous locations (Class I, II or III) | 1a/a | | | 3c | | | 4c | | |
| (11) Transformers | 2b/b | | | 3c | | | 4c | | |
| (12) Voltage regulators | 1a/a | | | 2b | | | 3c | | |
| (13) Battery banks and chargers | 2b/b | | | 2b | | | 3c | | |
| b. Cut, bend, and thread conduit | 2b/1a | | | 3c | | | 4c | | |
| c. Install and connect circuit extensions using | | | | | | | | | |
| (1) Conduit | 2b/b | | | 3c | | | 4c | | |
| (2) Nonmetallic sheathed cable | 2b/b | | | 3c | | | 4c | | |
| (3) Surface raceway | 1a/a | | | 2b | | | 3c | | |
| 12. MAINTAINING AND REPAIRING INTERIOR DISTRIBUTION SYSTEMS, MOTORS, AND CONTROL CIRCUITS | | | | | | | | | |
| SR: AFM 91-17; AFR 91-4 | | | | | | | | | |



Figure 3–10. STS Qualitative requirements.

task is a part of the airman's duty position, the supervisor must give the airman qualification training through OJT to bring him or her to the 2b proficiency level. You may see a task coded "1a/-." This coding indicates that the course does not teach the task. Not teaching the task or teaching it to a lower proficiency level by the course could be caused by lack of time or safety factors. For example, an STS task "Install and connect service entrances," is coded "2b/b." The "b" indicates that the students are taught the task knowledge only. It would be too costly to teach task performance. This task is better taught through on-the-job training.

The scale values in columns 2A, 3A, and 4A show the extent of training needed on each job element through on-the-job training for the award of the 3, 5, and 7 skill levels respectively. Columns 2B and 2C, 3B and 3C, and 4B and 4C provide space for a record of OJT progress and its certification.

**Exercises (069):**

1. The STS task and knowledge statements in column 1 are based upon what document?

2. Why are study/references included in column 1?

3. Explain the term "AFSC/Crs" in the headings of columns 2A and 4A.

4. 4. How is 3-skill-level upgrade training accomplished if column 2A has the words "no basic course" printed on it?

**070. State how the STS is used as a basic training control document and explain the conversion of an STS to a JPG.**

The STS As A Training Control Document. Each airman's training folder (AF Form 623) must contain a JPG. A JPG consists of an annotated STS and (if needed) an AF Form 797, Job Proficiency Guide Continuation Sheet. The AF Form 797 is used only if the airman's duty position requires performance of tasks which are not listed on the STS.

Convert the STS to a JPG by designating the specific job tasks. The STS may contain as many as 150 or more separate tasks. All the same, if the airman performs only 25 of these, plus 3 locally assigned tasks, fill in the JPG only to the extent of the 28 applicable tasks. List the 3 locally assigned tasks on AF Form 797. Identify the 25 tasks on the STS by circling the code key (in pencil). Figure 3-11 gives you an example of tasks that are identified (column 3A). Once proficiency training starts, record the date in column B (3B in our sample). Once training is completed, record the date and initial it. Have the trainee initial it as well (column 3C). Should the proficiency level be different from that on the STS, you can upgrade it (2a to 3c) but *not* downgrade it.

Once all tasks are identified on the STS, list the locally assigned tasks on AF Form 797. For each task, record the necessary S/TRs, circle the appropriate skill level, and record the date OJT starts. Notice that there are columns for the Date OJT Completed, Trainee Initials, and Trainer Initials. The paragraph and page numbers should correspond to the associated paragraph and page number on the STS.

**Exercises (070):**

1. Why is the STS considered the "basic training document?"

2. How are tasks for a duty position identified on the STS?

3. How is the completion of proficiency training for a task shown on the JPG?

4. What tasks are recorded on AF Form 797?

5. In addition to tasks on AF Form 797, what else must be added for each task?

**071. Specify the actions necessary to make JPG assignments and indicate how qualification training is recorded on the JPG.**

Use of the JPG. Once the tasks have been identified on the JPG and proficiency training has begun, use the JPG to record completion of and to have an available record of proficiency training. Look again at figure 3-11. Notice that some tasks have twpo or more action verbs. If the trainee is responsible for all, then the initials in column C indicate proficiency for the entire task. If, for some reason, training can be given on only one part of the task, circle and initial the appropriate verbs in pencil.

Once upgrade training is completed (all assigned tasks are signed off), the JPG is a basis for recommending upgrade action, provided the other requirements are met (career knowledge training and time).

However, even after upgrading action is complete, the JPG is used to record qualification training. This training is

| 1. TASKS, KNOWLEDGE AND STUDY REFERENCES | PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2. 3 SKILL LEVEL | | | 3. 5 SKILL LEVEL | | | 4. 7 SKILL LEVEL | | |
| | A AFSC /Crs | B Date OJT Started | C Date Compld & Trainee's Supervisor's Initials | A AFSC | B Date OJT Started | C Date Compld & Trainee's Supervisor's Initials | A AFSC Crs | B Date OJT Started | C Date Compld & Trainee's Supervisor's Initials |
| 7. ELECTRICIANS TOOLS AND TEST EQUIPMENT | | | | | | | | | |
| a. Select and use | | | | | | | | | |
| SR: AFP 85-1; AFR 127-101; TOs 32-1-101, 32-1-151 | | | | | | | | | |
| (1) Electricians handtools | 2b | | | 3c | | | 4c | | |
| (2) Portable power tools | 2b | | | 3c | | | 4c | | |
| (3) Soldering equipment | 2b | | | 3c | 1 Jul 82 | 20 Jul 82 JEP JAP | 4c | | |
| (4) Manual conduit benders | 2b/1a | | | 3c | | | 4c | | |
| (5) Manual conduit threaders | 2b/1a | | | 3c | | | 4c | | |
| (6) Power conduit benders | | | | 3c | | | 4c | | |
| (7) Power conduit threaders | 1a/a | | | 3c | | | 4c | | |
| b. Select and use (JAP) electrical or electronic | | | | | | | | TO ADVANCED COURSE | |
| SR: TO 31-1-141 series and 33A1 series | | | | | | | | | |
| (1) Meters | 2b | | | 3c | 1 Jul 82 | 1 Jul 82 JEP JAP | 4c | | |
| (2) Test equipment | 2b | | | 3c | | | 4c | | |
| 8. ELECTRICAL FUNDAMENTALS | | | | | | | | | |
| SR: TO 31-1-141 series | | | | | | | | | |
| a. Electrical principles | B | | | C | | | C | | |
| b. Interpret electrical terms and symbols | 2b | | | 3c | | | 4c | | |
| c. Construct basic electrical circuits | 2b | | | 3c | 1 Jul 82 | 20 Jul 82 JEP JAP | 4c | | |
| d. Measure electrical properties in circuits and components | 2b | | | 3c | 1 Jul 82 | 10 Jul 82 JEP JAP | 4c | | |
| e. Compute for voltage, current, resistance, and power | 2b | | | 3c | | | 4c | | |
| f. Transformer theory and application | B | | | C | | | C | | |
| g. Basic electrical power sources | B | | | C | | | | | |
| 9. ELECTRONIC FUNDAMENTALS | | | | | | | | | |
| SR: TO 31-1-141 series; ANSI Y32.2 | | | | | | | | | |
| a. Electronic principles applicable to tasks listed in this STS | | | | B | | | C | | |
| b. Interpret electronic terms and symbols | | | | 2b | | | 3c | | |
| 10. PLANNING AND LAYING OUT WORK | | | | | | | | | |
| SR: AFM 88-15 (chap 7); MIL STD 15-3 | | | | | | | | | |

PENCIL ENTRY

ALL INK ENTRIES IN THIS COLUMN

ALL PENCIL ENTRIES IN THIS COLUMN

 Attachment 1

Figure 3–11. Job Proficiency Guide (JPG), sample page.

recorded in a manner identical to that for upgrade training. Each time your airmen change duty positions, you must perform an evaluation which includes a review of all previous JPG entries. Then you must determine the extent of training required for the new position. If an airman is previously qualified on the task, you determine whether the airman is still qualified. If not, establish a qualification training program for that task.

**Exercises (071):**

1. How is the assignment of part of a task statement made on the JPG (only one of two action verbs)?

2. If a task has two action verbs and proficiency training is given on both, how is qualification on this task shown on the JPG?

3. How is qualification training recorded on a JPG?

4. If an airman is found to be unqualified on a task on which he or she was previously qualified, what must you as the supervisor do?

**072. State how to handle a new or revised STS, how to process an airman's JPG upon arrival at a new duty station, and this disposition of the JPG.**

**Processing of the JPG.** The JPG for the individual's current skill level(s) (both UGT and qualification training) is required to be maintained in the training folder. If the individual is dual qualified, JPGs for both AFSCs are kept in the folder. If an airman enters retraining, in addition to the current JPG being used for retraining, retain the JPG(s) for the training-out AFSC until the trainee has attained a skill level equal to the highest level held in the previous AFSC. You can give JPGs for previous skill levels to the individual unless you must records training for the current skill level on the same JPG. For example, if Amn Jane Smith has been upgraded to the 5 skill level, you must record her 7-skill-level training on a different JPG and give the JPG with the record of 5-skill-level training to Airman Smith.

What must supervisors do when a new or revised STS arrives for one of their trainees? Luckily, you are not required to redo the JPG completely if all required training can be done using the old STS.

When the new STS is received, review it to see whether all required training can be done using the old JPG. Annotate it with the date reviewed, sign it, and file the annotated STS copy with the master JPG.

When a trainee is transferred to another duty section, the new immediate supervisor, along with the trainee, reviews all pencil entries (training assignments) on the JPG. If a training capability for that phase exists in the new section, the training on that item is continued until it is completed. If a training capability does not exist, or if training is not required, erase all pencil entries. Whenever a previously certified task is not required in the present position, erase the circle in column 2A, 3A, 4A (fig. 3-11), or in AF Form 797 for the appropriate skill level which specifies that the task is required. This step is followed so that the JPG will continue to reflect the tasks applicable to the airman's present position assignment. It does not in any way affect certification of the task.

**Exercises (072):**

1. What should be done with a JPG once an airman has been upgraded to the 5 skill level and has to be placed into UGT to the 7 skill level?

2. Under what circumstances would there be two JPGs in an airman's training folder?

3. What must you do when you receive revised STSs?

4. What must you do to the JPG to reflect that a trainee is no longer responsible for performing a task for which he or she is qualified?

5. A JPG should show which tasks?

**073. Cite the purpose and use of AF Form 623.**

Although the JPG is the record of proficiency training, it is not a complete picture of an airman's training. Other records must be documented to show CDC completion and other training applicable to the AFS.

**AF Form 623.** This form is a comprehensive record of AFSC-oriented oriented training. This means that only the training associated with the AFS is recorded on or stored in the form. Off-duty courses at a civilian school are not recorded. It has four pages—in the shape of a common manila folder. It can be filed in the same manner as the manila folder. It is shaped so that the JPG and other pertinent training forms can be included as part of the form.

AF Form 623 is designed to contain all pertinent information for management personnel to use in making decisions and to reflect the *current* history of an airman at any particular time. Supervisory personnel use the form in determining whom to recommend for upgrade action, when

qualification training is necessary, and in making assignments or recommending personnel for positions. The primary purpose of the form is training documentation. Through this documentation, the Air Force assures that airmen are trained in their AFSs to a particular standard so that they can perform predictably, effectively, and efficiently.

The AF Form 623 has sections which permit the recording of all upgrade training, qualification training, and retraining, when conducted on the job. Also, there are sections for recording CDCs, ECs, and formal courses completed.

**Exercises (073):**

1. What is the primary purpose of AF Form 623?

2. What is the definition of AF Form 623?

3. Identify statements that define the uses of AF Form 623 by placing an "X" in the appropriate blanks.

____ a. A record of an airman's UGT from the helper to the advanced skill level.
____ b. Contains a record of an airman's current training history.
____ c. Used to record courses completed at a local college.
____ d. Used by supervisory personnel to maintain a record of an airman's training progress.
____ e. Used by supervisory personnel to determine when qualification training is needed.
____ f. Used to record qualification training and upgrade training.
____ g. Used by supervisory personnel to determine whom to recommend for promotions.
____ h. Used by supervisory personnel to determine whom to recommend for upgrading.
____ i. Contains a record of each CDC volume completion.

**074. State how to prepare and maintain AF Form 623, and, when given situations concerning an airman's training, state how to make the entries in the training record.**

**Contents of AF Form 623.** AF Form 623 is not complete until the JPG (consisting of an annotated STS) for the appropriate AFS is included. Inclusion of the JPG in the AF Form 623 provides the data necessary for completing job knowledge and job proficiency training and recording all qualification training. Once the JPG is inserted into the AF Form 623, it becomes an official part of the individual's training record. The immediate supervisor and trainer use the AF Form 623, along with the JPG, to maintain a cumulative record of an airman's training progress.

Because the AF Form 623 must be available to the immediate supervisor, it is maintained at the lowest level of supervision having facilities for the storage and maintenance of forms. In most cases, this is the immediate work unit. When an airman is transferred, the AF Form 623 with all appropriate current data inserted (manual or automated forms) accompanies the airman's field records group to the training organization. The airman's training is continued unless specifically withdrawn by the gaining organization. File in AF Form 623 any AF Form 2095/2096 and/or appropriate orders issued by the gaining organization to continue or discontinue training.

AF Form 623, prepared in one copy, is a permanent record which reflects the entire range of an airman's progression. However, the need may arise to insert an AF Form 623a, On-the-Job Training Record—Continuation Sheet, in the training record. AF Form 623a provides space to continue a section of the AF Form 623 when that section is completely filled. Remove all AF Forms 623a from the training folder that are not applicable to the airman's current OJT training objective. For example, if an airman is training to the 5 skill level, an AF Form 623a with entries pertaining only to 3-skill-level training should be removed from the folder.

The following documents should be included in the training folder when applicable:

*a*. AF Forms 1098, 2095, 2096, and 2097, Classification Board Action, and/or special orders that have a direct influence on the airman's training—for example, entry into training, removal from UGT, upgrade action, or extensions in training time.

*b*. The appropriate STS(s)/JPG(s).

*c*. AF Form 623a.

*d*. AF Forms 797.

*e*. AF Form 1096, CDC Status Record, and ECI Forms 9, Report of Course Examination and Report of Volume Review Exercise. Remove these forms when the individual completes UGT to the skill level for which the CDC is required.

*AF Form 497, Air Force Policy Statement—Firearms Safety and Use of Force, and 2400 series.*

*g*. Data automated products. The procedures listed in this objective segment pertain primarily to nonautomated training documentation requirements. Once an approved automated training system or subsystem is implemented, the following documentation procedures apply:

(1) When the automated product becomes available, it will be used in lieu of manual forms or selected parts of the manual forms described in this section.

(2) Those products that duplicate AF Form 623 entries or other training forms required by AFR 50–23 are not required to be maintained in the training folder unless determined necessary by the MAJCOM/DP and the functional user. However, those automated products that are not maintained in the AF Form 623 must be inserted in it when the airman is TDY in support of an operational commitment in excess of 30 days or when departing PCS.

*h*. Other documents or copies of documents which, in the opinion of the MAJCOM DCS/P(DCS/T for AFRES and DPT for ANG), are necessary to provide a complete picture of the airman's overall training status. Do not insert certificates of completion in AF Forms 623.

An AF Form 623 must be maintained for each individual in grades E–1 through E–6 and for each airman in grades E–7 through E–9 who is in retraining.

This policy does not prevent MAJCOMs from directing the maintenance of AF Form 623 for E–7 through E–9 personnel whose duties are such that an active training record would be beneficial. Examples are EGRESS personnel, nuclear weapon technicians, instructors, medical lab technicians, and others.

Upon separation, retirement, or promotion to pay grade E–7, give the AF Form 623 to the individual, unless it is required as stated above.

All entries in AF Form 623 may be made with typewriter, ink, pencil, or any combination of the three.

Use figures 3-12 and 3-13 to follow the instructions for completing the AF Form 623.

Section I, Identification Data, and Section II, Orientation and Certification, make up the front (first page) of the form. Enter the trainee's name, grade, SSAN, primary AFSC, duty AFSC, and training to AFSC. In our example, let's use the 54251 as the training to AFSC and the date entered training as of 18 July 1981. The estimated training completion date is based on criteria in AFR 50–23. In this case, normal upgrade training, 6 months from 18 July, would be 17 January 1982. General AQE score is 60. The dates for evaluations are figured as follows: The supervisor's evaluation (from Table 2-2, AFR 50–23, Active Forces; Table 2-5, ANG/AFRES) is not later than (NLT) the 8th month of training. Therefore, if this airman has not completed UGT by 17 March 1982, the supervisor must evaluate the trainee. If the supervisor recommends additional training and the airman is not upgraded by the end of the 12th month, then the commander must evaluate the trainee. The date for commander's evaluation is 17 July 1982. The maximum training date is NLT the 18th month of training or 17 January 1983.

In those instances where the number of CDC volumes cause an airman to exceed recommended time limits (6 months, normal UGT to the 5 skill level), add 1 month per volume, plus 1 month for the CE. If the airman in the example above has a six-volume CDC, the estimated training completion date would be 17 February 1982.

In Section II, when supervisors enter their name and grade, they are certifying that they have briefed the trainees on items "a" through "g" when entered into UGT. The final block in Section II is signed only if the AF Form 623 has been reaccomplished because of a mutilated, dirty, or illegible form.

Section III (fig. 3-13) was designed for recording Achievement Test Scores. However, these achievement test scores are on file in the Base Education Office and are no longer recorded in the AF Form 623.

In Section IV, ECI/CDC Participation, etc. enter all CDCs, ECs, USAFI, DANTES, and other correspondence courses satisfactorily completed. In column "A," enter the course number and title. In column "B," indicate the total number of volumes in the course; in column "C," indicate the date on which the CE was administered.

In Section V, Technical and Supervisory Training, list all technical and supervisory courses satisfactorily completed. Typical entries are limited to formal technical schools but include FTD courses, training management classes, NCO Leadership School, etc.

The May 1976 edition of AF Form 623 has no Section VI, but the March 1974 edition does. You will see both in your maintenance of these forms. Page 4 contains Section VI in the March 1974 edition. In the May 1976 edition, page 4 is blank.

Recall that AF Form 623a is the continuation sheet for any section of the AF Form 623 that is filled. Probably, Section VI of the March 1974 edition is filled at this date. If not, the following information should be recorded in this section:

*a*. Name, grade, date, and action taken as a result of evaluations required by table 2-2, AFR 50–23 (supervisor, commander, and final).

*b*. Dates of time periods and circumstances under which completion of the training objective (training to AFSC) is delayed.

*c*. Appropriate information to indicate that the trainee is not enrolled in the available required CDC and reasons why.

The above information should be entered into AF Form 623a if you have a trainee with a May 1976 edition of the AF Form 623 or if Section VI is filled for a trainee with a March 1974 edition.

Anytime an ink entry is changed, place correction tape over the entry. Then enter the correct information on the correction tape. Dull finish transparency tape may be placed over blocks subject to change to make erasure easier and to protect the form.

**Exercises (074):**

1. Where is the AF Form 623 maintained?

2. What is the purpose of AF Form 623a?

3. Under what circumstances can you give the AF Form 623 to an airman?

4. Where (what section) and when does the trainee sign AF Form 623?

5. When a trainee is administered the CE, what AF Form 623 actions should you take?

| IDENTIFICATION DATA | | | | |
|---|---|---|---|---|
| LAST NAME - FIRST NAME - MIDDLE INITIAL | PAFSC | DATE ENTERED TRAINING | GENERAL AQE SCORE | DATE FOR SUPERVISORY EVAL |
| | DAFSC | | | DATE FOR COMDR EVAL |
| GRADE / SSAN | TNG TO AFSC | ESTIMATED TNG COMP DATE | | MAXIMUM TRAINING DATE |

ON-THE-JOB TRAINING RECORD

*(THIS FORM IS AFFECTED BY THE PRIVACY ACT OF 1974)*

*AUTHORITY: 44 USC 3101; 10 USC 8012 and EO 9397*
*PRINCIPAL PURPOSE: AF Form 623 and all documents filed in the folder are used to maintain an individual comprehensive record of AFSC oriented training.*
*ROUTINE USES. 1. To document and monitor upgrade and retraining skill progression and qualification training by the trainer and supervisor.*
*2. As a historical document by supervisors to determine an individual's trained qualifications to perform required duties on initial assignment and on an "as required" basis thereafter.*
*3. To determine when entry into or withdrawal from training is required.*
*4. To determine if adequate training has been given when determining the proper recommendations to make regarding individuals.*
*5. To determine the effectiveness of the OJT program.*
*6. When waiver actions are requested in the OJT program.*
*7. When an individual is being considered for separation from the Air Force.*
*8. When required, to determine appropriate corrections to an individual's records.*
*DISCLOSURE IS MANDATORY. Failure to provide information will prevent required control monitoring of AFSC training which will jeopardize the ability of the unit to perform its assigned mission and will also prevent higher headquarters from knowing the skill qualifications on personnel in its units. The SSAN is mandatory to make positive identification of the individual in relation to other personnel actions and records.*

| II. ORIENTATION AND CERTIFICATION | |
|---|---|
| IMMEDIATE SUPERVISOR (GRADE AND NAME) | BRIEFS YOU ON SECTION TRAINING PROGRAM AND EXPLAINS THE FOLLOWING<br>a. YOUR AFS DESCRIPTION. AFM 39-1<br>b. TRAINING REQUIREMENTS. AFM 50-23 AND JPG<br>c. UPGRADING AND PROMOTION. AFR 39-29<br>d. APPRENTICE KNOWLEDGE TEST (AKT) PROCEDURES. AFM 35-1<br>e. PROFICIENCY TRAINING. AFM 50-23<br>f. EXPLAINS USE OF AF FORM 623, STS AND JPG. AFM 50-23<br>g. CERTIFIES COMPLETION OF JPG TASK ITEMS. AFM 50-23 |
| TRAINEE SIGNATURE | I CERTIFY THAT THE ACTIONS LISTED ABOVE HAVE BEEN ACCOMPLISHED AND THAT I UNDERSTAND MY INDIVIDUAL RESPONSIBILITIES FOR CAREER PROGRESSION AS ESTABLISHED IN AFM 50-23. |
| SIGNATURE AND TITLE OF CERTIFYING OFFICIAL | I CERTIFY THAT THIS AF FORM 623 IS A COPY OF PERTINENT DATA CONTAINED IN A PREVIOUS AF FORM 623. |

AF FORM MAY 76 623 PREVIOUS EDITION WILL BE USED.

Figure 3-12. AF Form 623 (front).

BEST COPY AVAILABLE

| III. READING ACHIEVEMENT TEST | |
|---|---|
| PART I (DATE AND SCORE) | PART II (DATE AND SCORE) |
| | |

| IV. ECI/CDC PARTICIPATION, ETC | | | | | |
|---|---|---|---|---|---|
| COURSE NUMBER AND TITLE A | NO. OF VOLUMES B | DATE COMP (MO/YR) C | COURSE NUMBER AND TITLE A | NO. OF VOLUMES B | DATE COMP (MO/YR) C |
| | | | | | |
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| V. TECHNICAL AND SUPERVISORY TRAINING | | | |
|---|---|---|---|
| COURSE NUMBER AND TITLE | DATE COMPL | COURSE NUMBER AND TITLE | DATE COMPL |
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SE-0236

Figure 3–13. AF Form 623 (back).

6. What is the estimated training completion date entered on AF Form 623 for airmen taking a 5-volume CDC who entered training 21 June 1978?

7. If an airman's date entered training is adjusted, what other dates should be adjusted on the AF Form 623?

8. In what section of AF Form 623 should you enter the following:

   a. Date entered training?

   b. Completion of Extension Course 9?

   c. An FTD course?

   d. An ATC resident course?

9. How should you change an ink entry on AF Form 623?

**075. State who is responsible for initiating and maintaining AF Form 1096, and specify its use and disposition.**

**AF Form 1096.** While the trainee is completing the required CDC, you need some method to monitor the trainee's progress. The AF Form 1096 is the prescribed form to use. The form is maintained by both you and the unit OJT manager (see fig. 3-14). the latter The OJT manager initiates the form in two copies and sends the forms to you. You establish a completion schedule when the first volume is assigned for study. Then, you return one copy to the OJT manager. While the entries on the form are self-explanatory, special guidance is provided for unusual circumstances. Section 1, CDC No.: When the trainee is enrolled in more than one CDC, all currently required CDCs will be entered in this block. Prefix the CDC number to indicate number 1, number 2, etc. Also, prefix the date ordered and received in the same manner to correspond with the CDC No. block. Section II: Enter each CDC volume or unit for ECI Course 9. The estimated completion date is the best date for the trainee to complete the volume or unit.

| I. PERSONAL DATA | | | |
|---|---|---|---|
| LAST NAME-FIRST NAME-MIDDLE INITIAL | GRADE | SSAN | DUTY SECTION |
| TRAINER | CDC NO. | DATES: ORDERED | DATES: RECEIVED |

| II. CDC INFORMATION | | | | | | | |
|---|---|---|---|---|---|---|---|
| VOL | DATES: EST COMPL | DATES: COMPLETED | SCORE | VOL | DATES: EST COMPL | DATES: COMPLETED | SCORE |
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| III. COURSE EXAMINATION RESULTS | | | | | |
|---|---|---|---|---|---|
| CE NO. | DATE ADMIN | RESULTS | CE NO. | DATE ADMIN | RESULTS |
| | | | | | |
| | | | | | |

AF FORM JUN 73 1096 CDC STATUS RECORD

Figure 3-14. AF Form 1096.

Enter the estimated completion date for each volume as assign it for study. However, you will have established and entered the course completion schedule when you assign the first volume for study. Enter the date the trainee completes the VRE in the date completed block. Section III: Enter the CDC number in each block. The date administered is the date the trainee is given the CE.

Once the ECI Form 9, Report of Course Examination, is received with a satisfactory score, remove the AF Form 1096 from the AF Form 623 and destroy it.

**Exercises (075):**

1. Who must maintain the AF Form 1096?

2. What is the purpose of AF Form 1096?

3. When is the AF Form 1096 removed from the training folder?

4. When is the course completion schedule set up?

5. Who initiates AF Forms 1096?

**076. State the purpose of AF Form 1098, and explain the meaning of certain entries made on the form.**

**AF Form 1098.** This form (fig. 3-15) may be used to document selected special task qualifications of a critical nature, selected tasks requiring recurring training or evaluation, and selected tasks where the supervisor relies on someone else to validate the individual's qualifications. When used, it becomes a part of the AF Form 623. Additionally, Air Force and MAJCOM directives may identify tasks contained in the STS that require special certification or recurring training or evaluation. Qualifications for these selected tasks may be documented on the AF Form 1098 instead of on STS. This form consolidates the status of qualifications of a critical or recurring nature, so that you can readily them without screening all routine entries in the JPG and AF Form 623a. The form may be disposed of when all of the entries are noncurrent. The form may be overprinted at command, wing, or unit level to standardize common entries and reduce administrative workload. Those items of a permanent nature may be entered on a separate form. When you are initiating the form for recurring entries, give consideration to grouping entries with the same recurring date, such as monthly, quarterly, semiannually, and annually. Leave an appropriate number of spaces between entries in column A to preclude the need for reentering the information at frequent intervals. Draw heavy black line across the form to inclose the required number of entry lines. Then, as reevaluations are completed, make the appropriate entries in columns B through H. Line out noncurrent entries. Although, for the most part, the blocks are self explanatory, the following paragraphs explain the entries to make on the AF Form 1098. Leave blank any nonapplicable column.

Column A—Enter the selected special task and the applicable directive that requires qualification of training.

Column B—Enter the type of evaluation such as P for practical or W for written. When both a practical and written evaluation are required, draw a diagonal line in the applicable columns B through E to separate the required information. When the entry pertains to training, enter C for classroom, P for practical, or SS for self-study.

Column C—Enter the date the evaluation or special training was completed.

Column D—Enter the score, rating, or when required by the applicable directive, the number of hours of training received.

Column E—Enter the date refresher training or reevaluation is required.

Column F—Enter the name or signature of the evaluator or instructor, when other than the supervisor or certifying official, and when this information is required by the applicable directive. An entry in this column does not consititute certification of an individual's task qualification, unless accompanied by an entry in column H.

Column G—Have the trainees initial to indicate that they are aware of and agree with applicable entries.

Column H—The supervisor or the certifying official signs here. Print the name of the certifying official here when you transcribe the entry from some other source document unless otherwise specified in the applicable directive. An entry in this column indicates that the individual is qualified to perform the applicable task without direct supervision. When the evaluation is accomplished by someone other than the supervisor or certifying official, you as the supervisor, sign this column indicating the individual is qualified. Name, SSAN, and grade are self-explanatory. Enter the current control AFSC of the individual in the space of AFSC.

You can make entries in ink or pencil, or you can type them, except for the grade and AFSC which you must write in pencil.

You review the AF Form 1098 during the initial evaluation. Then, you place your initials in column H for entries that are current and that the individual is qualified to accomplish in the new duty assignment. Reevaluation will not be required for those entries that you initialed until the due date indicated in column E of the form. Line out entries that you find are not current or that require refresher training or reevaluation. Reenter them when the required action is completed.

## SPECIAL TASK CERTIFICATION AND RECURRING TRAINING

| TASK OR RECURRING TRAINING AND STUDY REFERENCES<br>A | EVALUATION OR TRAINING: TYPE<br>B | DATE COMPLETED<br>C | SCORE OR HOURS<br>D | DUE DATE<br>E | EVALUATOR OR INSTRUCTOR<br>F | TRAINEE INITIAL<br>G | SUPERVISOR OR CERTIFYING OFFICIAL<br>H |
|---|---|---|---|---|---|---|---|
| MOUTH TO MOUTH RESUSUTATION AFR 127-101 | C | 20 July 76 | 1-HR | 20 Jul 77 | [illegible] | JRL | EOFulcher |
| CLOSED CHEST CARDIAC MASSAGE AFR 127-101 | C | 20 July 76 | 1 HR | 20 Jul 77 | [illegible] | JRL | EOFulcher |
| AFR 127-12 Annual Job Safety trng | C | 13 June 77 | 1 HR | 13 June 78 | [illegible] | JRL | EOFulcher |
| CPR AFR 127-101 | C | 3 Aug 77 | 2 HR | 3 Aug 78 | [illegible] | JRL | EOFulcher |
| AFR 127-12 Annual Job Safety trng | C | June 78 | 1 HR | June 79 | [illegible] | JRL | EOFulcher |
| AFR 127-101 CPR training | C | July 78 | 2 HR | July 79 | [illegible] | JRL | EOFulcher |
| AFR 127-12 Annual Job Safety Trng | C | 25 June 79 | 1 hr | 25 June 80 | [illegible] | JRL | EOFulcher |
| AFR 127-101 Annual CPR Trg | C | June 79 | 2 hr | June 80 | [illegible] | JRL | EOFulcher |
| MISSION APPLICATION SEMINAR | C | 27 June 79 | 1 hr | 1 June 80 | [illegible] | JRL | EOFulcher |
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| NAME OF TRAINEE *(Last, First, Middle Initial)* | SSAN | GRADE | AFSC |
|---|---|---|---|
| LEMMON, JACK R | XXX-XX-XXX | SSgt | T54250 |

AF FORM 1098 NOV 73 — BE-1098

Figure 3–15. AF Form 1098.

**Exercises (076):**

1. The AF Form 1098 is used to document what three things?

2. How does the form help you?

3. A "P/W" in the type of evaluation column means what?

4. Why must the trainee initial the Trainee Initial block after each task?

5. What entries on AF Form 1098 are not made in ink or typed?

6. A line drawn through all blocks of an entry means what?

**077. Associate the five phases of the Professional Military Education (PME) program to their corresponding title and state the objective of the PME program.**

**Professional Military Education.** Formal technical schools and OJT are, for the most part, designed to train you in the technical aspects of your career specialty, and increase your skill level. When you advance in skill level you will also progress in grade. As you are promoted to the higher noncommissioned officer (NCO) grades, you will find that your duties will change. You begin to move closer to the area of supervision. The higher you go in the NCO structure, the more you will be concerned with supervision, management and leadership. Professional Military Education is designed to prepare you for this higher status, and for positions of greater responsibility.

The PME program consists of five phases, each developed for personnel of particular grade and experience levels.

*Phase I, NCO Orientation Course.* This course is designed to prepare Senior Airmen for transition to NCO status. It will normally be completed in resident status prior to appointment as a sergeant, but may be completed through a correspondence course under certain circumstances.

*Phase II, USAF Supervisor's Course.* This course is designed to provide training for first line supervisors and working leaders. It is primarily for NCOs in the middle of the enlisted force structure. At present, this course is not available in correspondence course form.

*Phase III, NCO Leadership Schools (NCOLS).* NCOs in the middle tier of the enlisted force are the main targets of this base level course. NCOLS are designed to prepare junior NCOs to assume supervisory positions, and to provide job perspective in the areas specified in AFR 39–6, *The Enlisted Force Organization*. This course is also available in correspondence course form.

*Phase IV, Command NCO Academy.* Available in residence and through correspondence course, this course is for Staff Sergeants with a line number for Technical Sergeant through Master Sergeants. Its aim is to prepare selected NCOs for more advanced leadership and management responsibilities. Just like the NCOLS, the academy curriculum is designed around the requirements stated in AFR 39–6.

*Phase V, USAF Senior NCO Academy.* This is the highest level of PME that is available to NCOs. The residence version of this course is 9 weeks long, and is conducted by the Air University. Master Sergeants selected for promotion to Senior Master Sergeant through Chief Master Sergeants are eligible to go to this course. To those who cannot attend in residence a correspondence course is available.

**Exercises (077):**

1. For each PME phase represented below write the correct phase number (I–V) in the blank provided. Each answer is used only once.

____ a. NCO Leadership School (NCOLS).
____ b. USAF Senior NCO Academy.
____ c. NCO Orientation Course.
____ d. Command NCO Academy.
____ e. USAF Supervisors Course.

2. What is the objective of the PME program?

**078. Identify the components of motivation and state the methods of developing motivation.**

A training program would be of little use to you as a supervisor, unless the people who work for you have an interest and motivation in the OJT program.

**Developing Motivation and Interest.** Of all the responsibilities of a supervisor/trainer, that of motivating the trainee is perhaps the most important. The on-the-job

trainee needs motivation. Motivation can be defined as a driving force (as a need or desire) which causes a person to take action or move toward a goal. Motivation is also a mental state or attitude in which an individual is stimulated to take an active interest. We can say then, that, the components of motivation are a driving force, action, interest, and goals. As a supervisor you must create in your trainers a desire to teach. As a trainer you must create in your trainees a desire to learn.

It is important that you know something of the driving force and needs that cause individuals to take action. Your responsibility is to recognize and identify the needs of your people and then to determine ways to satisfy their needs through your training activities.

During your initial orientation and training evaluation you should have identified the training needs of your personnel. This evaluation should also include their personal needs and desires. These needs may fall into the area of physical or social needs. Although needs are individual, many are common to all of us. Several of these common needs are security, recognition, success, and self-esteem. A way of achieving these needs is to set a goal and then take action to meet that goal. The trainees should know the goals or objectives, and the driving force that you are trying to develop in them can be rooted to their needs. How can supervisors/trainers develop motivation in their trainees? This can be accomplished by responding to the needs of the individuals. In doing so you can create in them this all important ingredient, motivation. Their needs, then, become a tool you can use to develop motivation. Here are a few ways that may help in the development process.

*Enthusiasm*. Enthusiasm in the trainer becomes contagious. If you reflect this positive quality in your training methods, the trainee will be enthusiastic in return. It's that simple. If motivation is a problem, the cause may be a lack of enthusiasm on the part of the trainer and a lack of concern for the trainee. Most of the time, fast learners are easier to train because they require less attention. On the other hand, slow learners take more of your time and require much more attention. A little concern, patience, and enthusiasm will go a long way.

*Security*. How does a need for security affect trainees? Stop for a minute and think of how you felt when you started out your first day on the job. Certainly the new airmen feel much the same way when they encounter new environments with the difficult task of learning a new job. How can you help? Give clear instructions and complete assignments. Go over the training program in a logical sequence, don't just throw the whole thing at them in one large shovel full! Commend the trainees for a job well done. Provide an opportunity for them to talk over problems with you. If you apply these guidelines and some others you can think of, you will be able to build up their self-confidence and feeling of security.

*Recognition*. No one likes to be thought of as a number or just another trainee. We all have a need to be recognized. We all want the recognition we deserve, the approval of our friends, and above all the approval of our superiors. As a leader, you can reap many benefits by offering accurate, realistic praise and recognition to the trainees who have done good work. It bolsters their feelings that they are important and worth something to someone else. The effects of praise are profound. Recognition tells them that the group will do all it can to help them. This feeling aids in preventing a feeling of isolation that is so deadly for motivation.

*Success*. There is never so dismal a feeling as that of failure. Research has shown that many individuals who seek employment in the art of robbing banks do so out of a feeling of failure, more so than for the money. Suicides can and do relate directly to a perceived feeling that the person has failed. Satisfying the need for success is very important. People have little reason to try something they fear they cannot do. A feeling of inadequacy, and expectation of not being able to succeed, is one of the causes of deterioration in motivation. The supervisors/trainers can help by building the trainees' confidence in themselves by being supportive and encouraging, and particularly by breaking the training tasks and job assignments down into pieces which the trainees can do. Their job assignments should be meaningful and present a challenge, gradually increasing in difficulty and paralleling their training tasks. You might consider posting a training chart in the section in order to show the trainees how they are progressing. If they can actually see that they are successful it will prompt them to try still harder.

*Self-esteem*. This refers to the need to view ourselves favorably. We all want to feel adequate and confident in our ability to deal satisfactorily with our problems. If the trainees experience too many failures, they are likely to lose confidence in themselves and their ability. Success, on the other hand, is likely to cause people to feel adequate and confident in their ability to meet any situation, thus building self-esteem. In building your trainees' self-esteem, don't overdo the use of praise to the extent that you give them a false sense of accomplishment.

Motivation creates the desire to learn and is the key to a successful training program. As supervisors/trainers you must use all the techniques, methods, incentives, and ideas possible to create this desire within the trainees. You must point out to them how they will benefit from their OJT, how it will fulfill their needs, and how it fits into their overall job.

**Exercises (078):**

1. What is the most important responsibility you have as a supervisor or trainer?

2. What must a trainer provide to stimulate a trainee to take action?

3. What aids a trainee in his or her desire to learn?

4. How can supervisors/trainers develop motivation in their trainees?

5. List the appropriate individual need for each of the situations described.

   a. A supervisor posts a chart showing the progress each trainee is making.

   b. The trainer praises the trainee for a good job.

   c. A supervisor takes a newly assigned airman to the base substation and explains each distribution circuit and where it goes on base.

   d. The trainer shows great excitement toward the subject and is eager to help the trainee.

   e. An award is presented to trainees who score high on their examinations.

# Safety and First Aid

AS AN ELECTRICIAN in the Air Force, you will be both a craftsman and supervisor. You are marked as a craftsman by the excellence of your work and also by the safe manner in which you use to perform your skills. If you are a master of your trade you will seldom get hurt. You know your tools and equipment and keep them in proper working condition. You understand the dangers of your work environment and never take unnecessary chances. You study the rules of safety and have the wisdom to apply them as you work.

As a supervisor of the interior electric shop, you will not only be responsible for your own action but also for those of the people in your shop. You must see that all safety rules and procedures are followed. The base safety personnel know, beyond a shadow of a doubt, that unsafe working habits will eventually create an accident.

Part of your duties will be to see that your people know first aid procedures. If one of your people got hurt, would you and your workers know what to do? Could this person be properly administered first aid? Develop in your mind the attitude of following and obeying safety rules. They were developed first for your protection and second for the protection of the equipment you operate. In this chapter, we will cover safety and first aid as they apply to you as an electrician.

## 4-1. Safety Principles

Accidents are usually the result of a failure to think. You must think safety and use safe procedures. You must be aware of the hazards involved in your work. When you fail to think safety and practice safety, you are not only a danger to yourself but everyone working with you. One moment of carelessness may result in a serious injury or death. Therefore, it is part of your job as an electrician to practice safety at all times. Our goal in this section, then, is to present information that will cause you to think of the hazards and their causes in your work area and to think of the action to take for protection against these hazards and their causes.

**079. State the objectives of Ground Safety and the purpose of reporting unsafe conditions and accidents.**

Because of the dangers involved, you should be aware that safe and intelligent work habits are as important as a knowledge of electrical equipment. One of your primary objectives is to train yourself and the people you work with to recognize and correct dangerous conditions and to avoid unsafe acts.

Most accidents can be prevented if everyone cooperates to eliminate unsafe acts and conditions. *Webster's Third New International Dictionary* defines the word "accident" as "an event or condition occurring by chance or arising from unknown remote causes. This definition means that with adequate foresight most accidents can be prevented. Only 2 percent of all accidents are caused by natural phenomena such as lightning; 10 percent are caused by physical hazards; and 88 percent of the accidents are caused by unsafe acts of people, as shown in figure 4-1.

**Ground Safety.** To reduce accidents throughout the Air Force, a ground safety section has been established at each Air Force base. This ground safety section has a well-established safety program in effect at all times. You, the supervisor of a working crew, should carry out to the fullest extent possible all safety policies and procedures. This includes both those of the ground safety section and those of your local shop. Be sure that you include any directives passed on to you through safety meetings. The ground safety program is based on the fact that most accidents can be prevented before they happen! When safety is conscientiously practiced, injury to personnel and equipment will be at a minimum.

**Reporting Unsafe Conditions.** Each person has a responsibility to report unsafe working conditions. You, as a supervisor, receive these reports. You must then analyze the reported conditions and determine the proper corrective action to eliminate them. Conditions beyond your scope and ability to handle must be reported to your boss for immediate corrective action.

You can see that failure to carry out your responsibilities in safety training or to take action on reports of unsafe conditions can result in inefficient and costly operations. In addition, you will have the unpleasant task of reporting the accidents that are bound to follow.

**Accident Reporting.** Investigating and reporting accidents serve a vital function in the overall USAF accident prevention program. All MAJCOMs are responsible for investigating and reporting each accident and for maintaining a followup system to make sure that corrective action is taken. A personal report must be submitted by the commander of any subordinate unit that has an accident that causes death, serious casualties, or extensive property damage.

It should be noted that much time and expense is involved in investigating and reporting accidents. Although the majority of accidents are of a minor nature, they involve research of various publications, paperwork, and followup action. Therefore, instill in your workers the desire to think before they make a move.

**Exercises (079):**

1. On what fact is a ground safety program based?

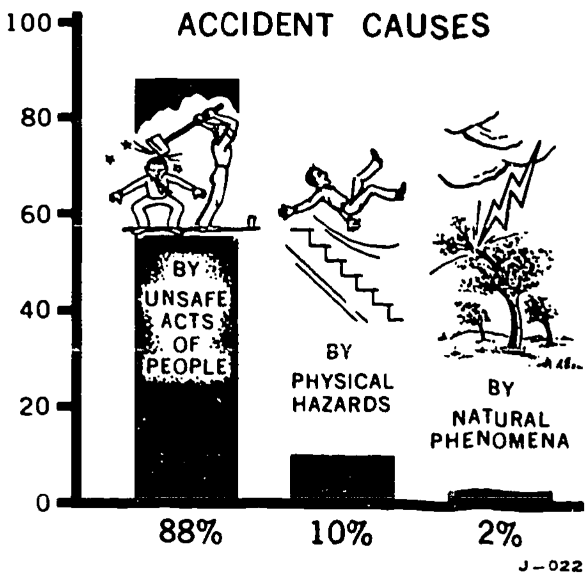



Figure 4–1. Accident causes.

2. What is the objective of the ground safety program?

3. Why should unsafe conditions be reported?

4. Why is it important to report each accident and maintain a followup system on accidents?

**080. Specify responsibilities for the working conditions and daily briefings in your shop.**

Your work as an electrician is one of the more hazardous jobs in the Air Force. At times, a good electrician has made only one mistake on the job. That one mistake caused serious injury or, in some cases, death. In dealing with the voltages that are common to your job, that one mistake could be your last one. If you are in a supervisory position, you have added responsibilities for making sure that the people who work for you are thoroughly briefed of the dangers involved. In every job, safety should be stressed. Shop safety briefings should be an important part of your job as an electrician and supervisor.

**Supervisory Responsibilities.** As a supervisor, you are re· ·nsible for certain duties. Some of these duties are:

Maintaining safe working conditions.

Insuring two qualified employees are working r when energized circuits of any amount of voltage ·ed.

nsuring that all employees understand and can .nister artificial respiration.

. Insuring necessary guards and protective equipment used and their proper use.

*e*. Insuring that tools and equipment are properly maintained and used.

*f*. Planning the work properly and seeing that it is performed in a safe manner.

*g*. Checking application of general and special safety instructions by your employees.

*h*. Assigning employees to jobs which they are capable of doing safely.

*i*. Taking immediate action to correct any violation of safety rules observed or reported to you.

*j*. Assisting in investigating all accidents.

You are also responsible for seeing that work under your direction is done in a safe manner. You should make sure that your people understand:

(1) The work to be done.

(2) The hazards that may be encountered.

(3) The proper procedure for doing the work safely.

**Daily Briefings.** Safety orientation of new airmen and employees is an effective tool for accident prevention. Daily briefings should be given to new workers until they are thoroughly familiar with the hazards in their working areas. All other workers should have a safety briefing at least once a week. The following guide will aid you in briefing employees about the work:

*a*. Check work area for hazards.

*c*. Check job print or sketch with employees.

*c*. Explain why the job is to be done.

*d*. Point out existing and potential hazards and discuss plans to control them.

*e*. Explain the work methods to be used.

*f*. Assign the work clearly and definitely.

*g*. Ask for questions and suggestions.

*h*. Make sure all employees fully understand their work assignments.

If the job involves special hazards or if there is any question as to complete understanding, ask the employees to repeat their work assignments and the work methods to be used. Repeat any directions or safety precautions that do not appear to be crystal clear about the work.

As a part of your routine duty, you should make frequent periodic inspections of equipment, materials, work areas, conditions, and methods. Such inspections are essential to prevent accidents.

**Exercises (080):**

1. What is an effective tool for accident prevention when new airmen are assigned?

2. Who should make a periodic inspection of equipment, materials, work areas, working conditions, and methods a part of his or her daily routine?

3. In the blank provided place an "X" if the statement indicates one of your responsibilities for working conditions or safety briefings in your shop. Correct the erroneous statements.

____ a. Insuring that necessary guards and protective equipment are available.
____ b. Assign the work clearly and definitely.
____ c. Explain the work methods to be used.
____ d. Give a safety briefing on only the most dangerous jobs.
____ e. Check the work area for hazards.
____ f. Don't explain why the job is to be done, since you are the boss and no one should question you.
____ g. Insure that all employees understand and can administer artificial respiration.

**081. State safe practices to use when doing electrical work.**

**Electrical Safety.** As an electrician, one of the major hazards which you encounter in your job is that posed by electricity. We shun an area when we see a sign reading: DANGER HIGH VOLTAGE. Why? Because we have heard it takes high voltage to kill and that low voltage does not kill. This is not true. Many people have been killed when they came into contact with a 120-volt house circuit. Others have been killed by lower voltage. Still other people have experienced shock from much higher voltages and suffered no injury. Since you never know what your body resistance is, avoid contact with any live circuit. When your body is wet, you offer less resistance to electrical shock than when you are dry. Never work with electricity when your body is wet, such as when you have been sweating.

Current flow through the human body is actually the cause of electric shock. Voltage causes the current to flow through the body; therefore, you are more likely to get a fatal shock from a high-voltage circuit. Some authorities state that a current flow of 100 milliamperes (1/10 ampere) through the human body is usually fatal. Electric shock interferes with your breathing process and paralyzes your muscles. When the shock is great enough, you lose consciousness in just a few seconds.

With your work in the electrical field, you must be fully aware of the hazards involved when working with electrical equipment. In fact, the more you know about electricity, the safer you can do your work. The rules given here are for your own safety and for the protection of the people who work with you. You should study them carefully until you are familiar with them. You must practice them until they become second nature to you. Among pilots the term called "forgiven error" refers to a mistake which did not result in disaster. This term can well be applied to your work in the electrical field. When you find that you have made one of these forgiven errors, you should review the events which led you to make this mistake. You will thus find the source of your mistake and be able to avoid a similar situation in the future.

Treat all electrical circuits as being live. This rule must be observed in all cases, except when you open the switch, make a voltage test, and know that the line is dead. In the case of long lines which are opened and grounded at some distant point, an inspection or test must always be made to find out what conditions exist. Remember that someone may accidentally close the wrong breaker, connecting your circuit to high voltage. Furthermore, to keep anyone from accidentally closing the breaker to a circuit which is undergoing repair, the breaker should be locked in the OFF position and tagged to indicate that the system is being repaired. A few general rules which must be observed in electrical work are as follows:

*a.* Do not wear identification tags when working around electrical machinery.

*b.* Do not wear jewelry or clothing with exposed metallic fasteners when working around batteries or electrical equipment.

*c.* Always use safety tools and devices wherever they are provided. This includes the following:

- Fuse pullers for removing or replacing fuses.
- Rubber floor mats around electrical panels.
- Rubber aprons when working on acid-type batteries.
- Work gloves when working around high-temperature equipment.
- Rubber gloves when working on live electrical circuits.

*d.* Always follow safe operating procedures. A person must never work alone on energized electrical circuits.

*e.* Don't struggle with a toolbox or an item which is too heavy to be handled conveniently.

*f.* Don't clutter your work area with unnecessary equipment. If you do not intend to use an item, store it in a safe place.

*g.* Always use the right tool for the job.

*h.* When possible, use handtools so that the working force is always directed away from your body. This will minimize the chances of injury in case the tool should slip.

*i.* Never put your hand on an electrical conductor unless you are working on a circuit and know that the circuit is dead. Always be sure that the switches to the circuits on which you are working are locked out and tagged.

*j.* Never try to remove a person or a tool from a live circuit with your hands or a piece of material which may be a conductor. Insulating material, such as a shirt or piece of dry rope, can be used as a loop to pull a person from a live circuit.

*k.* If battery acid should splash on you, immediately flood the affected part by washing with water. In cases involving the eye or face, flush thoroughly and immediately seek medical aid.

*Work on energized circuits.* AFP 85-1 *Electrical Facilities Safe Practices Handbook,* specifically states: "As a general rule, no work will be performed on energized electrical circuits or equipment. As an exception, work may be performed on energized circuits to prevent possible injury to others, or where critical missions will be jeopardized by interruption of service." If it becomes necessary for you to work on energized circuits, work only with other fully qualified electricians. Make sure you have the necessary protective equipment—rubber gloves, rubber blankets, rubber mats, etc. The type of work and the

conditions under which you work determine the exact type of protective equipment to use. One thing you must remember: safety equipment can become defective, so inspect it before you use it. A small crack or hole may make it unsafe for use. Do your job thoroughly: your life depends upon your thoroughness.

*Work on deenergized circuits*. Deenergized circuits do not present as great a hazard as do energized circuits. Nevertheless, you must be careful and observe safety rules. Make sure the circuit is deenergized by opening the switch. In some cases you may be able to lock the switch in the OPEN position. Where the switch cannot be locked, remove the fuses and attach a warning sign to the switch. Keep in mind that a circuit may become accidentally shorted to another circuit. For this reason, test the circuit with a voltmeter to make sure it isn't shorted and still "hot." You cannot afford to become careless, even when working on a "dead" circuit. Never lean against water pipes or other grounded devices when you work on any electric circuit.

**Exercises (081):**

1. Under what body condition do you offer less resistance to electric shock?

2. Which causes electrical shock, voltage or current? At what minimal amount?

3. How must all unproven circuits be treated?

4. Place an "X" beside each of the following work practices that are NOT safe.

____ a. Always wear ID tags when working around electrical machinery.
____ b. Remove your belt if it has a metal buckle when working around live circuits.
____ c. Use rubber floor mats when working on live electrical panels.
____ d. Work energized circuits alone to keep others out of your way.
____ e. Get help when lifting heavy equipment.
____ f. Leave tools laying around only while doing a job.
____ g. Use a screwdriver for its intended purpose only.
____ h. When working with a knife, always direct the blade away from your body.
____ i. You can put your hands on a bare conductor after the switch is locked out and tagged.
____ j. Remove a fellow worker from a live circuit any way you can.
____ k. Flush the affected parts of your body with water if battery acid is splashed on you.

5. What articles of protective equipment are necessary when working on energized circuits?

6. What could cause a "dead" circuit to become "hot" even when the switch is off?

**082. State safe clearance switching procedures and given statements concerning AF Forms 267, 268, 269, and 1492, associate each statement with the correct form.**

An important part of your job involves the safety supervision of electricians working on energized circuits. When working on electrical systems the locking and tagging of switches must be don-- under the direct supervision of a responsible person. These procedures involve the use of safe clearance forms. As an electrician and a supervisor, you must be familiar with these forms.

**Safe Clearances.** Do your work on electric circuits and equipment with the system deenergized whenever possible. Follow safe clearance procedures to deenergize a circuit, especially when it involves the opening or closing of a switching or disconnecting device that is out of sight from the working area. Use similar procedures when service to an operating activity will be interrupted. Safe clearance procedures are the responsibility of the base civil engineer. You should follow these procedures to complete maintenance on lines and equipment safely. The following information concerning the forms is taken from AFP 85–1 for your study and convenience.

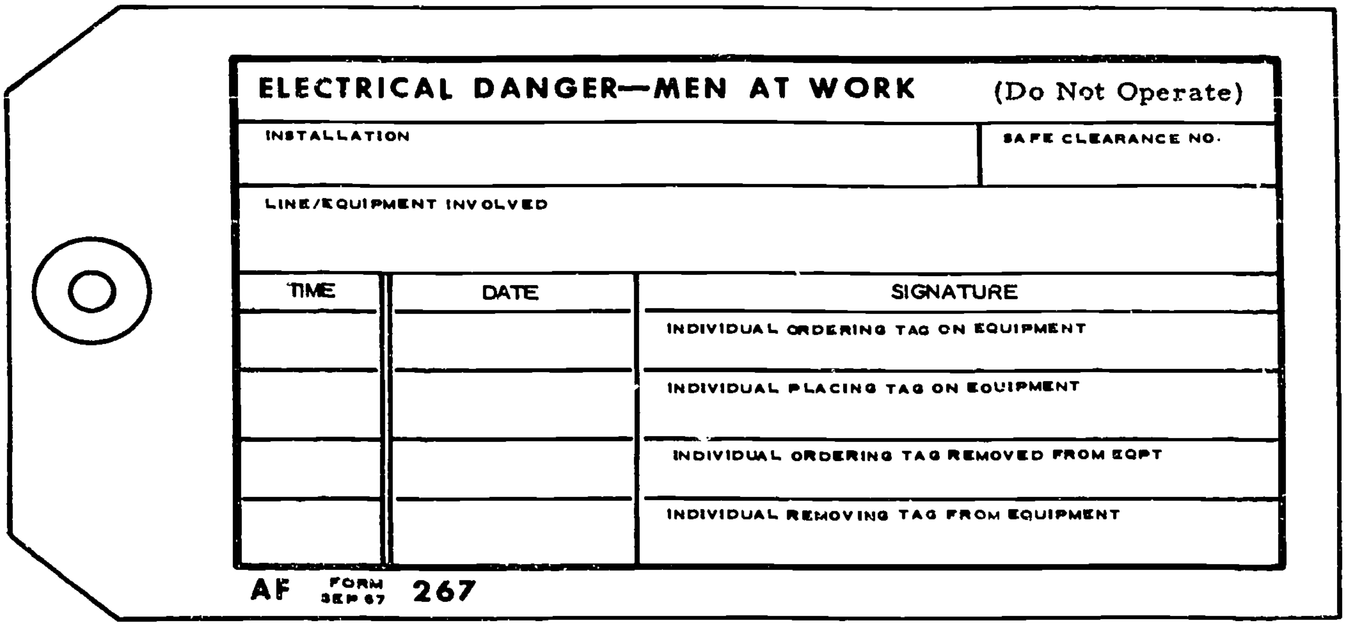
*AF Form 267, Electrical Danger - Men at Work, (Red Tag)*. This form is used in connection with AF Form 269, Electrical Facilities Safe Clearance. AF Form 267 is shown in figure 4-2. It must never be used for other than the protection of workers working under a safe clearance.

AF Form 268, Caution—Abnormal Conditions (Yellow Tag). This form is used to indicate abnormal operating conditions of line or equipment. It must never be used for the protection of those working under a safe clearance but may be used to show abnormal conditions brought about by a safe clearance. For example, this form should be used to tag a normally open switch which has been closed to tie two circuits together, preparatory to taking a section of one of the circuits out of service on a safe clearance. Also, switches on the distribution system which are normally open and must remain open under a safe clearance will be yellow tagged. This form is shown in figure 4-3.

*AF Form 269, Electrical Facilities Safe Clearance*. This safe clearance form must be used to control and record all blocking and tagging actions performed on electrical circuits. A copy of this form is shown in figure 4-4. Use the following procedure for filling out the AF Form 269.

*a*. Record number. Assign consecutive numbers from records maintained by the responsible issuing office.

*b*. Other clearance numbers. If more than one safe clearance (AF Form 269) is to be issued on the same circuit or equipment, show numbers of other clearances here.



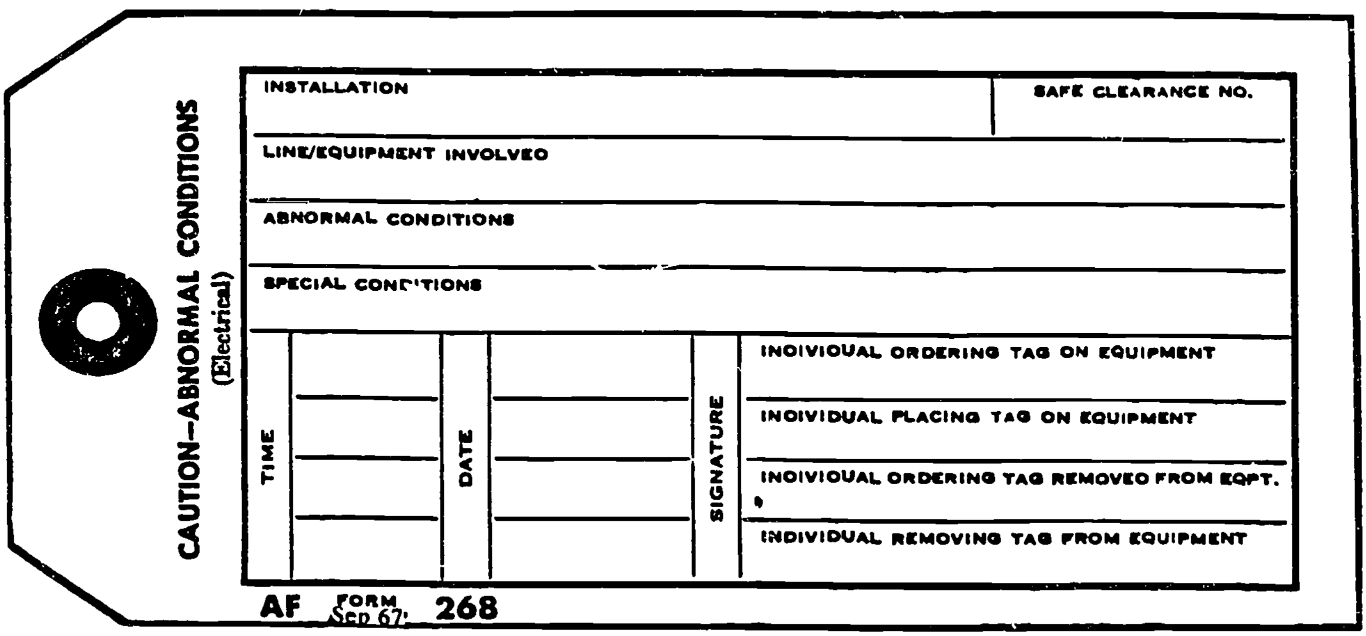
ELECTRICAL DANGER—MEN AT WORK (Do Not Operate)

| INSTALLATION | SAFE CLEARANCE NO. |
|---|---|
| LINE/EQUIPMENT INVOLVED | |

| TIME | DATE | SIGNATURE |
|---|---|---|
| | | INDIVIDUAL ORDERING TAG ON EQUIPMENT |
| | | INDIVIDUAL PLACING TAG ON EQUIPMENT |
| | | INDIVIDUAL ORDERING TAG REMOVED FROM EQPT |
| | | INDIVIDUAL REMOVING TAG FROM EQUIPMENT |

AF FORM SEP 67 267

Figure 4–2. AF Form 267.



CAUTION—ABNORMAL CONDITIONS (Electrical)

| INSTALLATION | SAFE CLEARANCE NO. |
|---|---|
| LINE/EQUIPMENT INVOLVED | |
| ABNORMAL CONDITIONS | |
| SPECIAL CONDITIONS | |

| TIME | DATE | SIGNATURE |
|---|---|---|
| | | INDIVIDUAL ORDERING TAG ON EQUIPMENT |
| | | INDIVIDUAL PLACING TAG ON EQUIPMENT |
| | | INDIVIDUAL ORDERING TAG REMOVED FROM EQPT. |
| | | INDIVIDUAL REMOVING TAG FROM EQUIPMENT |

AF FORM Sep 67 268

Figure 4–3. AF Form 268.

| ELECTRICAL FACILITIES SAFE CLEARANCE | RECORD NO. | OTHER CLEARANCE NOS. |
|---|---|---|
| ISSUED BY *(Name of installations electrical supervisor)* | TIME | DATE |
| NAME OF EMPLOYEE RECEIVING CLEARANCE | | |
| LINE/EQUIPMENT INVOLVED | | |

| TIME APPLIED | DETAILS OF BLOCKING AND TAGGING | TIME REMOVED |
|---|---|---|
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| RELEASED BY | ACCEPTED BY | TIME RELEASED | DATE RELEASED |
|---|---|---|---|
| | | | BE-269 |

AF FORM SEP 67 269

Figure 4–4. AF Form 269.

*c*. Issued by. Fill in the name of the person who issues the clearance, the time, and the date of issuance.

*d*. Name of employee receiving clearance. Fill in the name of the person receiving the clearance. Safe clearances are issued only to employees authorized to receive them by the installation electrical supervisor, who maintains a list of all such employees. Generally, only one safe clearance form may be issued to a job, and, if more than one crew is assigned to the work, the holder of the clearance must be responsible for all the crews. When necessary, due to the distance separating the various crews or the extent of the work, as many safe clearances as required may be issued. In such cases, the installation electrical supervisor, or an employee designated by the supervisor, will act as general supervisor of the job and will issue and receive releases of all the clearances. The employee receiving a clearance checks all blocking and tagging and makes sure that all points of possible feed are open on all phases and are properly blocked and tagged. Workers will not be required to work on circuits or equipment under conditions that they consider unsafe.

*e*. Line or equipment involved. Give a brief, concise description of the circuits or equipment on which work is to be performed. This information may be filled in as much in advance of actual time of issuance as required.

*f*. Details of blocking and tagging. Blocking is defined as the placing of a prime mover valve, switch, or other circuit opening in the OPEN or CLOSED position, as the case may be. Blocking insures by mechanical means, or otherwise, that the position of the device will not be changed accidentally. Tags are applied to such devices to make sure that their positions will not be changed by unauthorized persons as long as equipment or circuits are blocked out and tagged under an active safe clearance. For example, a single-blade, stick-operated, disconnect switch which has been opened cannot ordinarily be mechanically blocked open but is red tagged on each phase. It is then considered to be blocked open by the presence of the red tags. Gang-operated switches are locked open and a single red tag applied to the lock. Likewise, a turbine throttle valve must be locked in the closed position and red tagged. Suitable tag holders of insulating materials, designed for installation with a switch stick, are provided for use on single-blade, stick-operated, disconnect switches; fused cutouts; open jumpers; and similar visible line breaks.

Red and yellow tags (AF Forms 267 and 268), applied under each safe clearance, will bear the safe clearance number and the name of the person to whom the safe clearance is issued. AF Form 267 (red tags) shall never be used except for the protection of people working under a safe clearance. AF Forms 268 (yellow tags) are used in connection with a safe clearance to show an abnormal position of a switch or other device (which does not require a red tag) and to insure that its position will not be changed. AF Forms 268 (yellow tags) are used only for the protection of circuits or equipment and must never be used for the protection of people working under the protection of a safe clearance.

Employees who received safe clearances are responsible for filling in all details of blocking, switching, and tagging in the spaces provided on the form. They fill in the spaces in advance of the beginning of switching, and have these details checked and approved by their supervisor. These details must be entered in their proper sequence, reading down on the form, and will include any switch moves necessary to transfer load or put other equipment into operation before deenergizing the circuits or equipment covered by the safe clearance form.

The issuing office supervisor makes any necessary arrangements for interruption of service or notifying users. This person also notifies the utility company supplying power to the installation prior to the performance of switching which may affect the utility company system.

*g*. Time applied. The installation electrical supervisor designates a switchperson to perform the switching, blocking, and tagging. The employee who is to receive the clearance may be authorized to perform these operations at the discretion of the electrical supervisor. Fill in opposite each detail of blocking, switching, and tagging the actual time each detail is performed, progressing downward in proper sequence on the form.

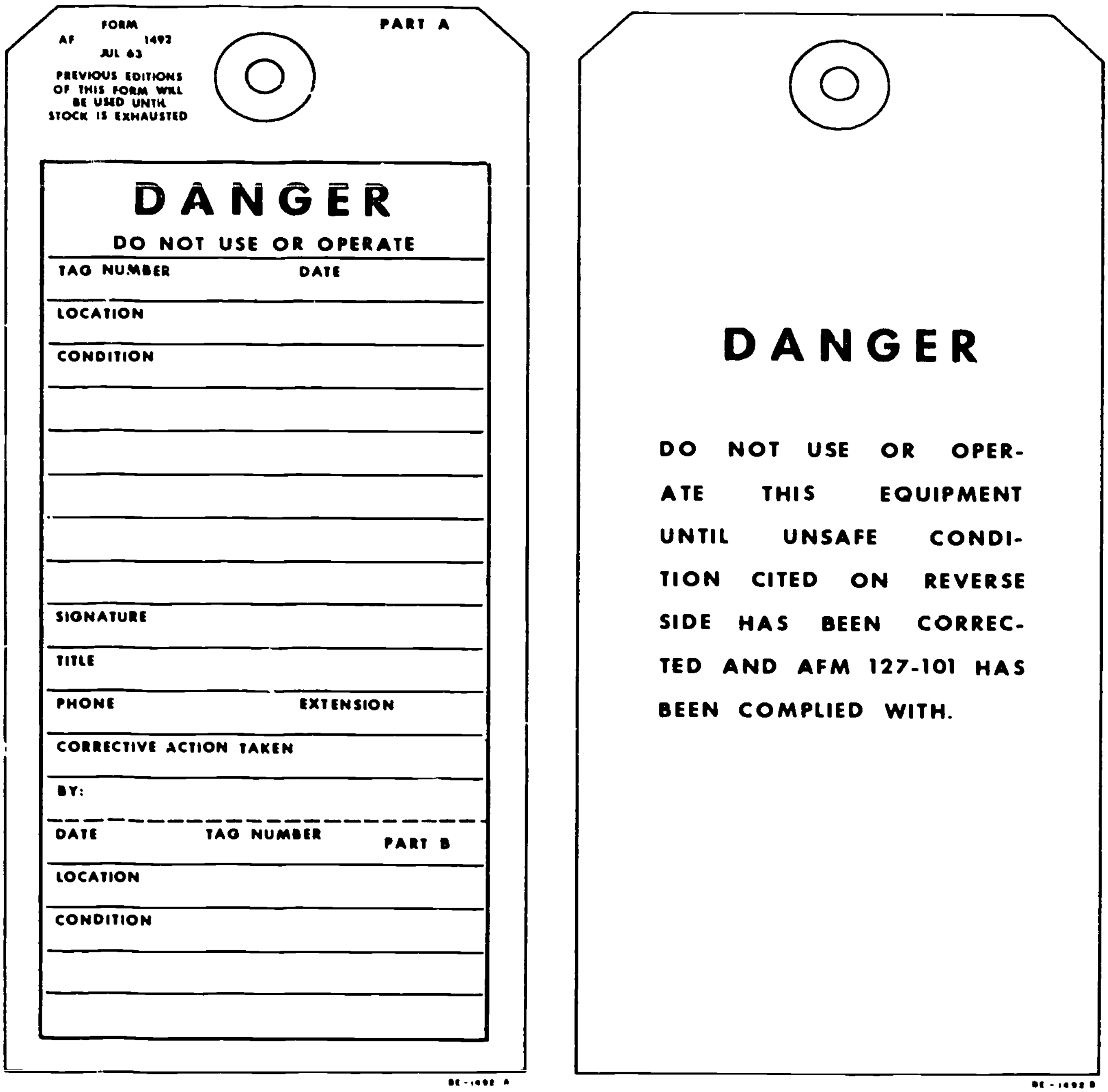
*h*. Released by. The person accepting release of the clearance fills in the name of the person releasing the clearance. The person releasing a clearance makes sure that all people and temporary grounds are clear and that the circuit or equipment is ready for service.

*i*. Accepted by. The person accepting release of the clearance fills in his or her name and time and date of release. If more than one clearance is used make sure that all clearances are released before any change is made in the blocking or tagging which would affect clearances which have not been released.

*j*. Time removed. If blocking and tagging have been applied for more than one clearance, no switching shall be performed until the clearances, with numbers corresponding to the numbers on all red tags and/or yellow tags on the switch, valve, visible line break, or other device of blocking, have been released. When releases have been received for all clearances, perform switching in reverse order from that in which it was applied. Beginning with the last detail of switching, blocking, and tagging applied, perform the opposite operation, progressing upward on the form, and enter the time each operation is performed. For instance, if a detail of switching, blocking, and tagging reads "Switch A open and red tagged," the opposite operation is "Red tags removed and switch A closed."

**Danger Tag, AF Form 1492.** This form, shown in figure 4-5, is NOT to be substituted for AF Forms 267 or 268. As stated earlier, these forms are used to indicate changed working conditions. AF Form 1492 is used to tag material and equipment no longer safe to use because of defects, abuse, or wear. It is not designed or intended for use in reporting minor hazards that should be corrected by the responsible supervisor.

If you are authorized by the Commander to attaCh the tag to a hazardous item, you will be responsible for completing parts A and B of the form. Part A will be attached to the hazardous item. Remove part B for use in correcting the condition. It should be noted that only the person who issued the tag, or a designated representative may remove part A of the tag.



FORM
AF 1492
JUL 63

PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED

PART A

DANGER

DO NOT USE OR OPERATE

TAG NUMBER | DATE

LOCATION

CONDITION

SIGNATURE

TITLE

PHONE | EXTENSION

CORRECTIVE ACTION TAKEN

BY:

DATE | TAG NUMBER | PART B

LOCATION

CONDITION

DANGER

DO NOT USE OR OPERATE THIS EQUIPMENT UNTIL UNSAFE CONDITION CITED ON REVERSE SIDE HAS BEEN CORRECTED AND AFM 127-101 HAS BEEN COMPLIED WITH.

Figure 4–5. AF Form 1492, Danger, Do Not Use or Operate.

**Exercises (082):**

1. Match the statement in column B to the correct form number in column A.

| *Column A* | *Column B* |
|---|---|
| ____ (1) AF Form 267. | a. This form is used to control all blocking and tagging performed on electrical circuits. |
| ____ (2) AF Form 268. | b. This form must never be used for other than the protection of personnel working under a safe clearance. |
| ____ (3) AF Form 269. | c. This form indicates abnormal operating conditions of a circuit or equipment. |
| ____ (4) AF Form 1492. | d. This form is used to tag equipment no longer safe to use because of defects, abuse, or wear. |

2. Who is responsible for notifying users when service is to be interrupted?

3. When will switching be done if blocking and tagging have been applied for more than one clearance?

4. Who is responsible for safe clearance procedures?

5. Under what conditions will it be necessary to work under unsafe conditions?

6. What is meant by blocking in reference to electrical circuits?

7. Why are tags placed on blocked switches?

8. What is marked in the "Time Applied" column of AF Form 269, Electrical Facilities Safe Clearance?

9. Which part of AF Form 1492, Danger Tag is attached to hazardous equipment?

## 4-2. Tool and Equipment Safety

Safety awareness is essential to an electrician. You will install, maintain, and repair electrical equipment where live voltages are frequently present. This work is often done in a limited space. Among the hazards of this work are electrical shock and electrical fires—which may be generated by faulty electrical equipment—and injuries that are caused by the improper use of tools and equipment.

**083. From a list of practices relative to the general use of handtools, identify those that are not safety practices.**

**Handtools Safety.** Poor maintenance and the improper use of common handtools result in many accidents which could be avoided if proper safety procedures were always followed. This objective covers safety procedures about handtools in general. These practices are as follows:

*a.* Keep tools sharp.

*b.* Keep tools in their proper places.

*c.* Replace handles that become splintered or loose.

*d.* Dress mushroom heads on cold chisels, punches, drift pins, etc.

*e.* Protect the edges of cutting tools with a sheath or by storing them separately from other tools.

*f.* Select a box-end wrench or a socket in preference to an open-end or an adjustable wrench as the former are less likely to slip. To help prevent slippage, always pull the wrench toward you.

*g.* Wear goggles or face shields when there is a possibility of flying chips, sparks, etc.

*h.* Hold small items that you are working on in a vise.

*i.* Never use a tool for anything other than what it is intended to be used for: i.e., don't use a hammer handle for pry bar, a wrench for a hammer, a knife for a screwdriver, etc.

*j.* Use screwdrivers for what they are designed—to drive and remove screws. Keep the blades ground and shaped properly at all times. Select the proper type and size of screwdriver for the job. Never hold an object in one hand while working on it with a screwdriver. Place it in a vise.

*k.* Use files and rasps with handles that are designed for them. Without the proper handle, a file or rasp is dangerous because it is easy for the tang to injure the palm of your hand.

*l.* Keep chisels and punches clean and sharp because it is easy for a dull or dirty tool to slip and injure you.

**Exercises (083):**

1. Place an "X" beside those of the following which are not good safety practices and correct the statement.

____ a. Use a screwdriver as a wedge.
____ b. Use a box-end wrench in preference to an open-end wrench.
____ c. Store all cutting tools with the other tools, without sheaths.
____ d. Wear goggles when drilling a hole above your head.
____ e. Hammer a rusted pipe union with a pipe wrench.
____ f. Keep tools sharp.
____ g. Sharpen screwdriver to a knife edge to cut wood.

**084. From situations indicating safe and unsafe operation of electrical power tools, distinguish between the safe and unsafe practices.**

Each year, scores of workers have been injured on the job because of neglect or because of not knowing that a dangerous situation existed. Sgt Eli Enis, an electrician, was using a grounded drill and was severely injured when he fell off a ladder after grabbing a moist water pipe as he was drilling a hole in a wall. As he touched the pipe, he received a severe electrical shock that passed from his right hand, through his body near his heart, and to his left hand which contacted the pipe. Although the voltage was only 110, the jolt frightened him. He fell sideways on a sawhorse, and the body of the drill hit him on the shoulder. This electrician was off duty for 3 weeks.

A 110-volt charge of electricity is dangerous, especially when you are working on damp or wet pavements and grounds. It can kill you, so be aware of electrical hazards and precautions as you use electrical-powered tools.

**Safe Operation of Electrical Power Tools.** As an electrician, you will use a variety of tools powered by electricity because they make your work easier and because they are faster and more efficient. However, because of their source of power, they can be hazardous unless you know how to guard against the hazards. The main hazards are from fire and shock caused from improper or no grounding and from cord abuse.

*Fire hazards*. Electric-powered handtools are a source of ignition for a fire if used near flammable materials or in explosive atmospheres, unless they are of the explosion proof type. You must be aware of this hazard as you work in areas which have dust and fumes.

*Improper grounding*. When you use power tools, check them to make certain that they have three-wire cords. The extension cord must also have three wires and be plugged into a grounded receptacle. Figure 4-6 shows how a drill motor equipped with a three-wire cord can protect the operator by providing a low-resistance path to ground for the current from a defective tool. It also shows what can happen to you with equipment that is improperly grounded.

*Double-insulated power tools*. A recent development in the manufacture of power tools has precluded the necessity for a case ground (green) wire, three prong connection. These tools are made with a standard two prong molded connector. This system became possible through the use of high-impact plastic suitable for tool housings or cases that will not conduct electric current. Since these cases are electrically inert, there is no danger of a live wire contacting the case and causing an electrical shock. All exposed metal parts of the tool are insulated from electrical power by high impact plastic through plastic gears or couplings. As these new tools are brought into the supply system, they will be so identified so as not to require a case ground connection.

*Cord abuse*. It is important to protect the cord on your power tools. This is also true of the extension cord. The conductors in the cord, the insulation on the cord, and the plugs must be protected if you are to have safe operation. Scrapes, kinks, or stretching, as well as grease and oil, will damage power tool cords or extension cords. Use heavy duty plugs which clamp to the cord. Do NOT jerk the cord to unplug from a receptacle. Jerking the cord can break the cord wires or cause the connections in the plug to become loose and may cause a short circuit.

Precautions you must take when you use electric power tools are included in the following list:

*a*. Inspect the equipment, especially the external wiring, before you use it.

*b*. Use safety glasses or face shields where chips or dust could fly or tools could break.

*c*. Do not wear loose gloves or loose clothing while using rotating equipment.

*d*. Exchange accessories with the power off and the cord unplugged. Remove guard if necessary.

*e*. The guard must be in placed before starting the tool.

*f*. Do not wear rings, metal-rimmed glasses, watches, or other metallic objects when working with electrical tools.

*g*. If you use equipment in damp locations, stand on a rubber mat and wear rubber gloves.

*h*. Be certain the tool is properly grounded.

*i*. Check the operating instructions prior to operating electrical tools. On large equipment these instructions are usually located on a data plate which is attached to the equipment. On smaller, portable equipment, go to the manufacturer's manual to find instructions.

*j*. Operate tools in accordance with manufacturer's instructions.

**Exercises (084):**

1. Identify each of the following situations as "S" for safe or "U" for unsafe procedures for electric-powered tools. Correct the unsafe practices.

____ a. Using a 2-wire extension cord.
____ b. Jerking plug from receptacle.
____ c. Ventilating area subject to petroleum vapors.
____ d. Operating electric motor in dust-filled room.
____ e. Using a heavy-duty plug which clamps to cord.
____ f. Tools operated on 110-volts need not be grounded.
____ g. Read operating instructions before operating an electric tool.
____ h. Never operate an electric tool in damp locations without protection.
____ i. Inspect equipment before you use it.
____ j. Remove jewelry before operating electrical tools.

**085. Given work situations, distinguish between those that contribute to unsafe use of power equipment and those that contribute to safe use.**

**Power Equipment Safety.** You can be severely injured by coming in contact with moving machine parts. Although the Air Force has prescribed standards for safety in the use of machines, you must use commonsense as you work with and around power equipment. Since machines are developed or changed frequently, you must be able to apply general safety rules to specific machines or specific uses of

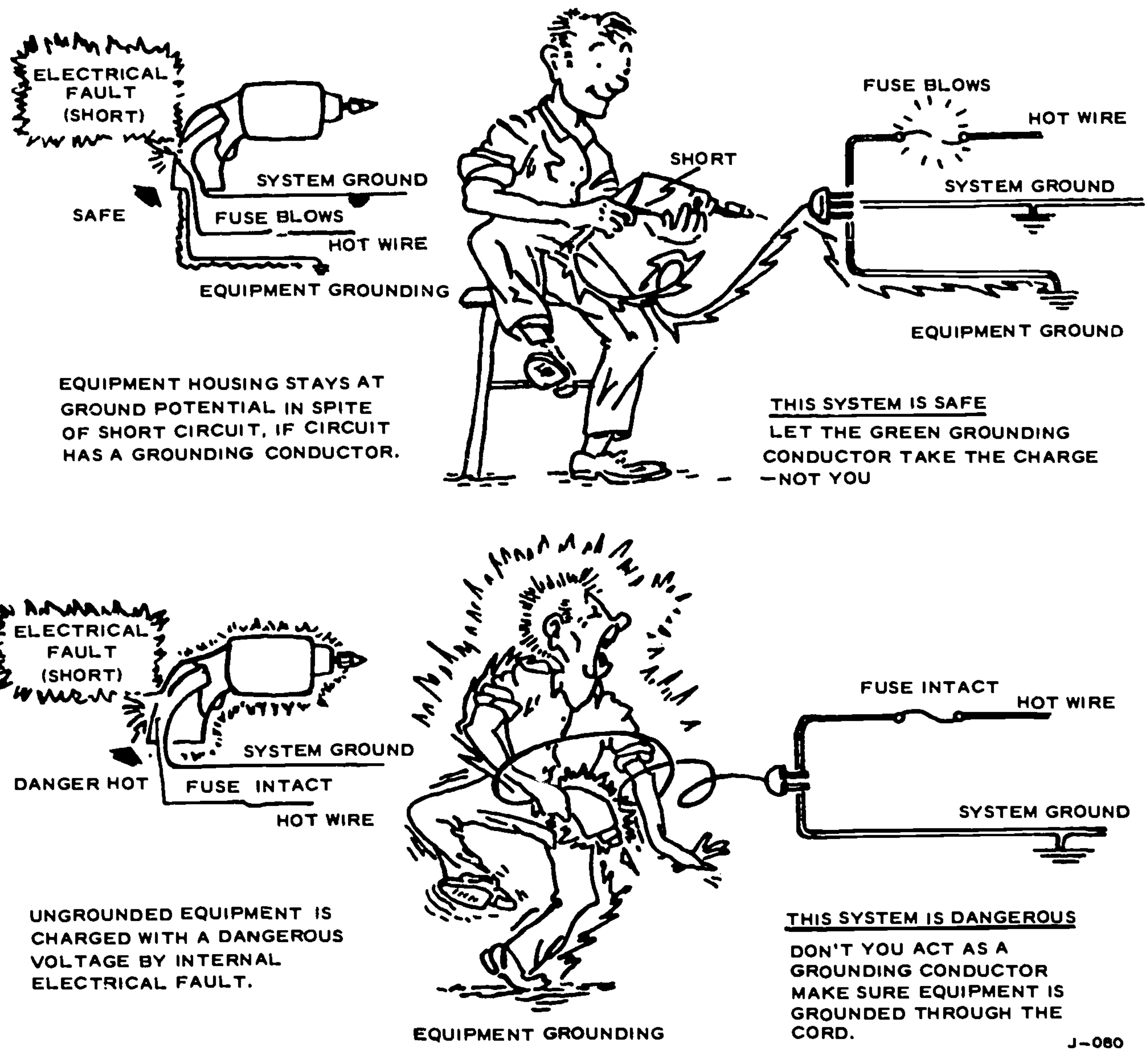



Figure 4-6. How equipment grounding works.

power machines. Some of the general rules that apply to equipment safety follow:

*a*. Do not wear jewelry, loose clothing, long sleeves, or gloves while operating machinery.

*b*. Use brushes to remove chips and metal particles. Do not use your hands.

*c*. Where the possibility of flying particles exists, wear goggles or a face shield.

*d*. Do not remove or block a machine guard while the machine is in operation.

*e*. You must be authorized in writing before you can operate a machine.

*f*. Do not leave machinery operating unattended.

*g*. Do not clean, lubricate, adjust, or maintain machinery while it is in motion.

*h*. Operate machines within recommended speeds.

*i*. Inspect a machine before operating it.

*j*. Electrically operated machines will be grounded.

**Exercises (085):**

1. Place an "S" before each of the following statements which indicates good safety procedures. Place a "U" before each statement which indicates an unsafe practice and correct the statement.

____ a. Inspect shop machines before operating.

____ b. Machines operated with motors of less than 2 horsepower require no ground.

____ c. Brush off metal cuttings from machines with gloves.

____ d. Use a face shield when grinding metal.

____ e. To facilitate lubrication, grease a machine during operation.

____ f. Remove ring and wristwatch before operating a machine.

____ g. Do not leave machine operating unattended even for 5 minutes.

**086. Differentiate between safe and unsafe lifting situations and sequence lifting steps in the correct order.**

In your day to day jobs, you will probably have to move heavy objects from one place to another. Knowing the correct procedures in lifting a heavy object is important in order to prevent injuries.

**Lifting Heavy or Cumbersome Loads.** When you must lift a heavy or bulky object from the floor, remember this advice: USE YOUR LEGS—NOT YOUR BACK. If you are not mindful of this advice, you can hurt your back. A hurt back is often difficult to heal and can keep you from taking part in many athletic activities. Figure 4-7, lifting tips, shows the way you should lift. Study the figure and pay particular attention to the feet, legs, and back. Lifting and setting down are the first and last movements performed in handling materials. When done by hand, it is during these movements that most strains occur. It is important that you follow these basic lifting techniques to reduce the possibility of injury:

*a*. Consider the size, weight, and shape of the object to be carried. Do not lift more than you can handle comfortably. If necessary, get help.

*b*. Set feet solidly with one foot slightly ahead of the other for increased stability. Place the feet far enough apart to give good balance.

*c*. Get as close to the load as possible. Bend legs about 90° at the knees. Crouch, do not squat. It takes about twice as much effort to get up from a squat.

*d*. Keep the back as straight as possible. It need not be vertical, but it should not be arched. Bend at the hips, not the middle of the back.

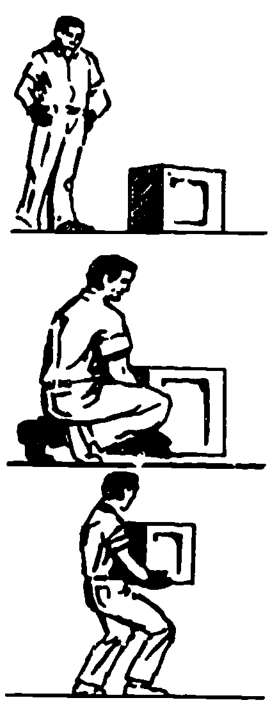



Figure 4–7. Lifting tips.

*e*. Grip the object firmly. Maintain the grip while lifting and carrying.

*f*. Straighten the legs to lift the object and, at the same time, bring the back to a vertical position.

*g*. Never carry a load that you cannot see over or around. Make sure the path of travel is clear.

*h*. Setting down an object requires that you follow the reverse procedures.

**Exercises (086):**

1. Mark the following situation "S" (safe) or "U" (unsafe), and state how to make the unsafe situations safe.

____ a. Lifting a 10 feet long bundle of conduit with a helper.

____ b. Lifting an object 4 feet in diameter that weighs 45 pounds by yourself.

____ c. Lifting a tool box weighing 10 pounds by bending at the waist.

____ d. Lifting a roll of wire (94 pounds) by yourself.

2. In the space provided, arrange the following steps for lifting a heavy load in the proper sequence.
   a. Keep your back straight.
   b. Squat down.
   c. Check weight and size.
   d. Plant your feet well apart.
   e. Lift slowly by pushing up with your legs.

**087. Associate the types of ladders with their proper use.**

**Selection of Ladders.** Much of the work you do will have to be done from a ladder. Serious accidents have been caused by electricians who use ladders improperly. It is important for you to know the right type of ladder for the job. The most common types of ladders that you will be using are the single ladder, extension ladder, and stepladder.

*Single ladder*. The single ladder used by the electrician consists of two side rails from 8 to 26 feet in length, with rungs spaced 1 foot apart. A good single ladder will support up to 500 pounds. The size of a ladder is determined by its overall length. Figure 4-8 shows a typical single wooden ladder.

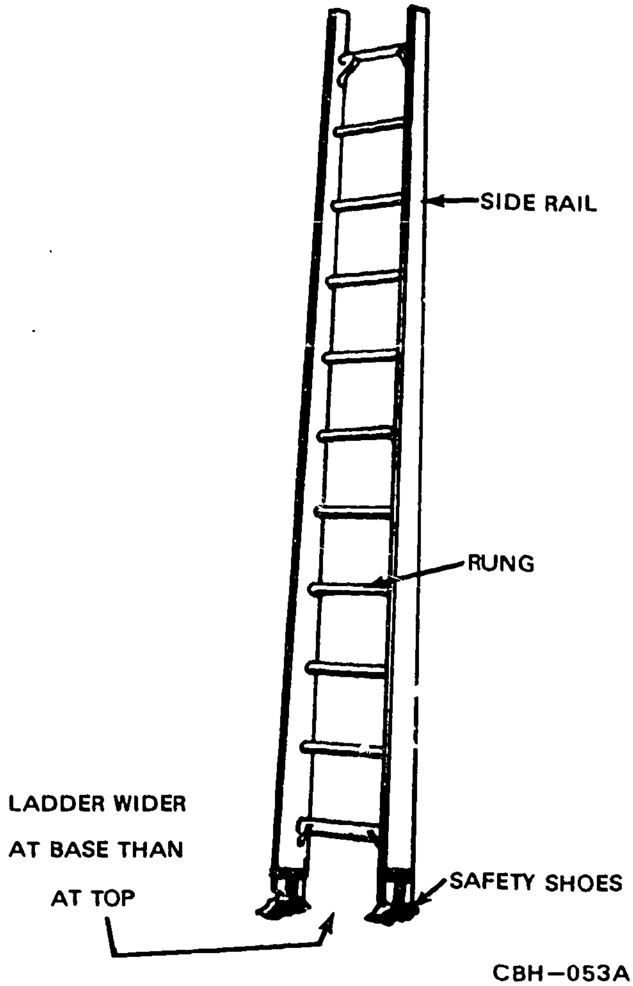



Figure 4–8. The single ladder.

*Extension ladder*. The extension ladder (see fig. 4-9) consists of two or more sections. These sections overlap and are extended by pulling on an attached rope. They are available in lengths up to 60 feet. Extension ladders are required by the electrician to do work of short duration, such as changing lamps, checking circuits, or getting onto a roof.

*Stepladder*. A stepladder is self-supporting (see fig. 4-10). This ladder can be used effectively as a portable work platform because it has wide rungs to make it easier to stand on for long periods of time. The most common size you will use is the 6-foot stepladder, but they are available in sizes up to 16 feet.

**Exercises (087):**

1. Match the uses of ladders listed in column A with the type of ladder in column B.

| Column A | Column B |
|---|---|
| ____ (1) Used to get onto a flat roof that is 30 feet high. | a. Single ladder. |
| ____ (2) Used in the middle of a room. Electrician removes a panel from a 9-foot ceiling to get to a circuit. | b. Stepladder. |
| ____ (3) Used to get onto a roof 10 feet high. | c. Extension ladder. |
| ____ (4) Used for a job requiring you to work for several hours. Your reach must extend 2 feet more than it can when you are standing at ground level. | |

**088. Distinguish between proper and improper ladder raising techniques.**

**Ladder Erection.** Raise a straight ladder by placing the base of the ladder (wide end) against the foundation of the structure. Lift the top and walk under the ladder toward the bottom end, grasping and raising the ladder rung by rung as you proceed. When the ladder is perpendicular, pull the bottom out from the building to a distance of one-fourth its length, as shown in figure 4-9. If you must get on top of the building, the ladder should extend at least 36 inches above the eave, (see fig. 4-11).

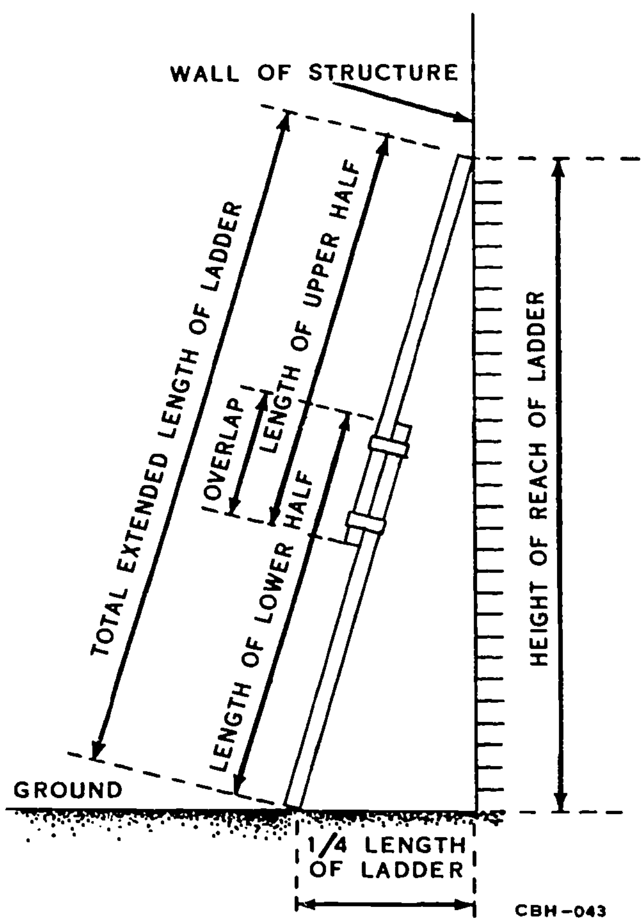



Figure 4–9. Extension ladder.

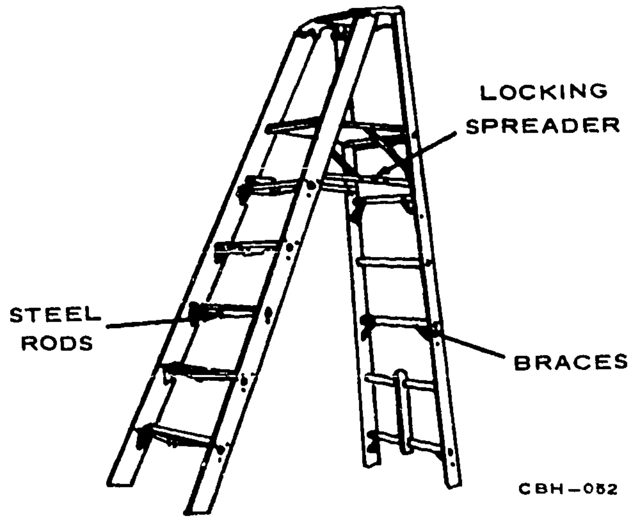


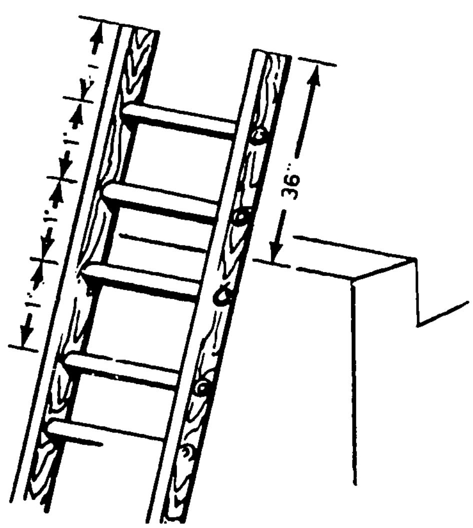

Figure 4-10. Stepladder.

With the extension ladder collapsed, position it in the same manner as the straight ladder. After the ladder is against the structure, extend the sections by the means provided until the ladder reaches the necessary height.

To put up a stepladder, spread the back legs away from the front legs until the locking device locks. This locking device keeps the legs from collapsing when weight is placed on the ladder.

**Exercises (088):**

1. Writes "Yes" before each of the following statements that indicate the proper ladder raising technique and "No" before each that indicates improper technique. Correct the improper techniques.




NOTE: LADDER SHOULD EXTEND AT LEAST 30" ABOVE BUILDING OR PLATFORM

CBH-045

Figure 4-11. Correct ladder height.

_____ a. The top of a 20-foot ladder extends 4 feet above the roof. The base of the ladder is 4 feet from the foundation.

_____ b. The top of a 10-foot ladder extends 36 inches above the eave.

_____ c. Extend an extension ladder on the ground before raising it.

_____ d. Spread a stepladder until the legs lock in position.

_____ e. Place the bottom of a straight ladder against a foundation to raise it.

2. What part of a straight ladder do you grasp with your hands when you erect it?

**089. Identify selected situations with the appropriate ladder safety precaution.**

**Ladder Safety.** Observe safety precautions when using ladders.

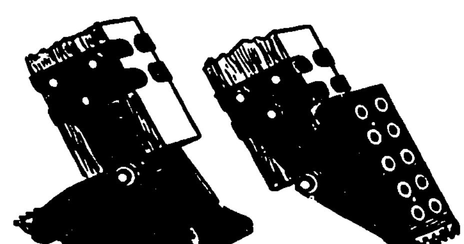
*a*. Always inspect a ladder before using it.

*b*. Before climbing a ladder, be sure that both rails rest on solid footing.

*c*. Equip the ladder side rails with safety shoes (see fig. 4-12). This is especially necessary when you use the ladder on surfaces that would permit the ladder to slip.

*d*. Under no circumstances would you use stepladders as substitutes for workbenches.

*e*. When you go up or come down a ladder, face the ladder and hold on to each side rail.



SAFETY SHOES

Figure 4-12. Ladder safety shoes.

*f*. When the security of a ladder is endangered by other activities, rope off the area around it, fasten it securely, and assign someone to steady the bottom.

*g*. When you use a ladder in front of a door, lock the door or block off the door and route personnel to another exit.

*h*. Never leave a ladder unattended for any length of time while it is erected—take it down and lay it on the ground.

*i*. When working from an extension ladder, stand no higher than the third rung from the top and do not attempt to reach beyond a normal arm's length.

*j*. If you need help to do the work, have your helper get another ladder—don't allow anyone on the ladder with you.

*k*. Never climb a ladder while using both hands to hold material; at least one hand must be used while climbing or descending a ladder.

*l*. Never place either the top or bottom of a ladder against unstable material.

*m*. Before climbing a stepladder, be sure it is fully open and locked and that all four legs are on solid footing.

*n*. Do not leave tools on the top of a stepladder unless it is equipped with a special holder.

*o*. Do not stand on either of the top two steps of a stepladder.

*p*. Never use metal ladders where there is a possibility of coming in contact with electric current.

*q*. Get help when erecting long, heavy ladders.

**Exercises (089):**

1. Match each of the following situations in column B with the applicable safety precaution in the column A.

| *Column A* <br> *Safety Precaution* | *Column B* <br> *Situation* |
|---|---|
| ____ (1) Safety shoes. | a. Climbing a ladder. |
| ____ (2) Do not stand on two top steps. | b. Working from an extension ladder. |
| ____ (3) Rope off the area. | c. Before climbing a stepladder. |
| ____ (4) Do not use near electrical apparatus. | d. Using stepladder. |
| ____ (5) Stand no higher than third rung from top. | e. Be sure ladder rails are equipped with these before climbing. |
| ____ (6) Face the ladder and use both side rails. | f. Use metal ladder. |
| ____ (7) Be sure locking device is locked. | g. Ladder placed in area of other activities. |

**090. From a list of presumed safety precautions related to handling chemicals or chemical solutions, distinguish between safe and unsafe precautions.**

**Chemicals and Chemical Solutions.** The types of chemicals with which you will most likely be concerned are those used for storage batteries. The chemicals are used as electrolyte for the batteries. The two you may come in contact with are sulfuric acid, used in lead-acid batteries, and potassium hydroxide, used in the nickel-cadmium batteries.

*Sulfuric acid*. The first precaution to observe in working with acids is the process of mixing them. The proper mixing procedure is always to add the acid to the water. Pouring small amounts of acid into a larger volume of water allows adequate cooling of the mixture. If this mixing procedure is reversed by pouring water into the acid, a violent reaction may occur and acid may be splashed over a wide area.

Sulphuric acid is dangerous to any part of your body, especially to your eyes. In the event of any contamination, the affected area must be flushed immediately with a solution of bicarbonate of soda and water. If the eyes become contaminated, immediately flushing with large volumes of water is important, and expert medical aid should be obtained at once. Sulphuric acid will also damage clothing, shoes, or just about anything with which it comes in contact. One more hazard of this unpleasant material is its possible explosion hazard. When a battery containing sulphuric acid is being charged, a quantity of hydrogen gas is given off. This hydrogen gas is highly explosive. For this reason, battery rooms or other battery charging areas must always be considered as a no smoking areas.

*Potassium hydroxide*. This is not an acid, but its use requires the observance of certain safety precautions. Potassium hydroxide (KOH) is very dangerous to the skin and eyes. It destroys tissues and causes severe burns. Breathing the vapors may result in injury to the respiratory system. Some safety precautions that you must observe in handling any battery electrolyte are listed as follows:

- Always wear full protective clothing, including gastight goggles.
- Use safety showers and eyewash fountains immediately upon contamination.
- Neutralize and flush all contaminated areas and equipment.
- Keep all battery areas well ventilated and do not breathe vapors from batteries.
- Treat lead-acid type battery areas as no smoking areas.

**Exercises (090):**

1. If the following precautions are safe, place an "S" in the blank space. If they are unsafe use a "U" and correct them.

____ a. Use full protective clothing when handling electrolyte.

____ a. Medical aid is not needed if eyes are flushed with water after being contaminated.

____ c. Ventilation is unnecessary for potassium hydroxide.

____ d. The proper mixing procedure for mixing acids is always to add the acid to the water.

____ e. Treat lead-acid-type battery areas as no smoking areas.

**091. Match types of flammable material with the classes of fire, and state the extinguishing agent to use on various types of fires.**

**Fire Prevention.** Although firefighting is the prime responsibility of the fire department, it is your job to prevent fires and to help put them out if they do start.

Good housekeeping is essential in the prevention of fires. If you let trash, waste, dust, and other residue build up, they become a source of fire. Oily rags, for example, can ignite by spontaneous combustion. You can prevent fires of this type by storing oily rags in a metal container with a lid (see fig. 4-13).

Another serious fire hazard is the accumulation of fuel vapors, gases, paint vapors, and other items of this nature. To eliminate this type of hazard, keep your shop clean and well ventilated. Prevent fires whenever you can, but also know something about the four classes of fires and something about how to fight them.

**Classes of Fires.** You can put out fires in each of the four classes by the use of a particular action or extinguishing agent. Some fire extinguishers do not work well on all classes of fires. Water, for example, may cause an oil fire to spread rather than put out the fire.

*Class A fires.* Class A fires are those occurring in wood, clothing, paper, rags, and other items of this type. This type of fire can usually be put out with water. Water provides the cooling and quenching effect necessary to extinguish class A fires. You may also use the soda-acid type extinguisher on this class of fire. Another type of extinguisher you can use on class A fires is the foam type. You may also use foam on class B fires.

*Class B fires.* Class B fires are those occurring in flammable liquids such as gasoline, fuel oil, lube oil, grease, paints, etc. The agents required to put out this type of fire are those which will blanket the surface of the fire. This action creates a smothering effect. The types of fire extinguishers for use on class B fires are foam, carbon dioxide ($CO_2$), and dry chemical. The dry chemical units contain a dry powder, usually sodium bicarbonate, and an activating agent of $CO_2$ or nitrogen gas. The dry chemical extinguisher is also used on class C and D fires.

Figure 4–13. Fire prevention at work.

*Class C fires.* The class C fires are fires in electrical equipment and facilities. The extinguishing agent for this type of fire must be a nonconductor of electricity and must provide a smothering effect. The dry chemical extinguisher is used for this purpose.

*Class D fires.* The class D fires occur in combustible metals such as magnesium, potassium, powdered aluminum, zinc, sodium, titanium, zirconium, and lithium. The extinguishing agent for this type of fire must be a dry-powdered compound which creates a smothering effect.

If you discover a fire, you should take certain actions. First, sound the alarm and alert all personnel. Second, you must call the base fire department and give exact directions to the location of the fire. You should take these first two actions quickly. Then, the personnel in the area should apply the most effective means available to put out or to contain the fire. When assigned to a new shop, you should find the fire extinguisher in the area. Also find out what types of extinguishers are available and how to operate them. This information is usually printed on the fire extinguisher.

**Exercises (091):**

1. Match the class of fire in column B with the flammable material in column A by placing the letter in the appropriate blank.

| *Column A* | *Column B* |
|---|---|
| ____ (1) Magnesium. | a. Class A. |
| ____ (2) Electrical equipment. | b. Class B. |
| ____ (3) Paper and rags. | c. Class C. |
| ____ (4) Gasoline and grease. | d. Class D. |

2. Name three types of extinguishing agents that are used on paper and wood fires?

3. What three types of extinguishers are used on gasoline and oil fires?

4. What type extinguisher is used on electrical fires?

## 4-3. First Aid

Of all the different tasks or jobs that you perform, knowing and being able to apply first aid procedures is one of the most important. In this section we will talk about the first aid you should know. This will include artificial resuscitation, closed chest cardiac message, bleeding, protecting and treating wounds, heat exhaustion, and shock. This section is not intended to qualify you as a doctor or a medical person, but it may help you save a life.

**092. State methods of artificial resuscitation and clarify rationales related to each procedures.**

Artificial respiration is a procedure used to cause air to flow into and out of the lungs of a person when natural breathing is inadequate or when it has stopped. Artificial resuscitation is used when a person has stopped breathing or when breathing is inadequate to sustain life. There are many ways to apply artificial respiration. Earlier methods included rolling the victim over a barrel, inverting the victim by suspension by the feet, and beating the victim with a whip. Believe it or not one method involved applying heat to a victim's chest by building a fire on the stomach. Fortunately, modern methods have replaced these primitive procedures. The most effective method and the one used by the Air Force is the mouth-to-mouth resuscitation method.

**Mouth-to-Mouth Method.** This method of artificial respiration has been proven the most effective. This method is simpler and saves more lives. This method works because normally you take only one-quarter of the oxygen out of the air that you breathe, leaving the rest for the victim.

Time is of prime importance. Resuscitation must be started at once if the person is not breathing. Use the following steps for giving mouth-to-mouth resuscitation.

(1) Place the victim face up. Do not put anything under the head, as it may flex the neck, causing the air passages to be blocked.

(2) Quickly clear the mouth of any foreign matter by running your fingers behind the lower teeth and over the back of the tongue. Wipe out any fluid, vomitus, or mucus (see fig. 4-14). This cleaning should not take more than a second or two, since little time should be lost in getting air into the victim's lungs.

(3) If available (do not waste time looking for these materials), place a rolled blanket or some other similar material under the victim's shoulders so that the head will drop backward. Tilt the head back so that the neck is stretched and the head is in the "chin-up" position (see fig. 4-15). This will aline the air passages so that they do not become blocked by kinking or pressure. At this point, you should check the victim's breathing. The victim may have started breathing when you tilted the head. This may be done by placing your ear over the victim's mouth and nose. Look for the chest to rise and fall. Listen for air and feel for

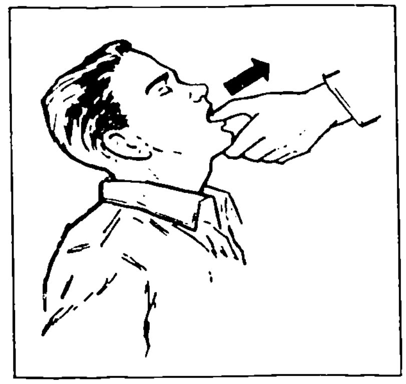


Figure 4–15. Open air passage.

flow of air on your cheek. If the victim is not breathing go to the next step.

(4) Place your thumb into the corner of the mouth and grasp the lower jaw firmly. Lift the lower jaw foward to pull the tongue forward out of the air passage. Do not attempt to hold or depress the tongue.

(5) Pinch the nose shut with your other hand to prevent air leakage.

(6) Take a deep breath and open your mouth wide. Seal your mouth around the victim's mouth and your thumb, and blow forcefully (except for infants and small children) into the mouth until you see the chest rise (see fig. 4-16). This is done to resupply the lungs with oxygen. If the chest does not rise, hold the jaw up more forcefully and blow harder while making sure there is no blockage of the air passage and no air leakage around the mouth or nose.

(7) Stop blowing when the chest rises and quickly remove your mouth from the victim's mouth. Take another deep breath while listening for exhalation. If exhalation is noisy, elevate the jaw further.

(8) When exhalation is finished, blow in the next deep breath. The first 3 to 4 breaths must be deep (except for infants and small children) and given at a rapid rate in order to provide rapid reoxygenation. Thereafter, continue breathing at a rate of 12 to 20 times a minute.

CAUTION: Excessively deep and rapid breathing may cause you to become faint, to tingle, and even to lose consciousness. Therefore, after the first 3 to 4 breaths, adjust your breathing to a rate of 12 to 20 times a minute

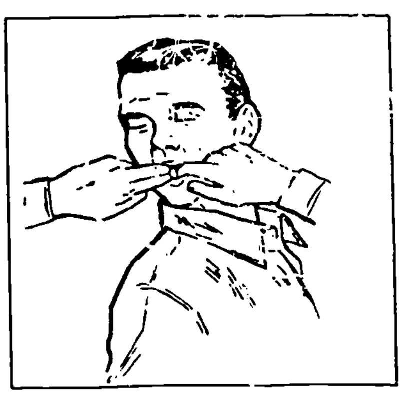


Figure 4–14. Clear victim's mouth of obstructions.

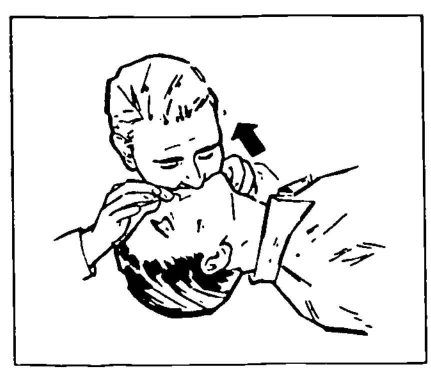


Figure 4–16. Seal victim's mouth and nose.

with only a moderate increase in normal volume. In this way rescue breathing can be continued for long periods without fatigue.

(9) After performing rescue breathing for a period of time, you may notice that the victim's stomach is bulging. This is due to air being blown into the stomach instead of the lungs. Although an inflation of the stomach is not dangerous, it makes inflation of the lungs more difficult. Therefore, when you see the stomach bulging to a marked degree, apply gentle pressure to the stomach with your hand between inflations.

(10) As soon as artifical respiration has been started and while it is being continued, an assistant should loosen any tight clothing about the casualty's neck, chest, or waist. KEEP THE VICTIM WARM.

(11) Continue artificial respiration without interruption until natural breathing is restored or until a physician declares that the patient is dead.

(12) To avoid strain on the heart when the victim revives, keep the victim lying down. Keep the victim warm, give the victim a warm drink, such as coffee or tea.

(13) Watch the patient. A brief return of natural respiration is not a sure indication for stopping the resuscitation. Not infrequently, the patient, after a temporary recovery of respiration will stop breathing again. If natural breathing stops, artifical respiration should be resumed at once.

**Alternate Methods of Resuscitation.** Mouth-to-mouth resuscitation is not the only way to revive a victim. There are several alternate methods that you may use. These methods may include mouth-to-nose, back pressure-armlift, and back pressure-hiplift. The reason you may have to use one of these alternate methods is that the victim may have facial injuries which would prevent you from using the mouth-to-mouth method.

*Mouth-to-nose method*. This method is basically done the same way as the mouth-to-mouth method. The steps are the same except you breathe into the victim's nose and not the mouth.

*Back-pressure-armlift method*. This method, shown in figure 4-17, may be used when the victim has suffered some type of mouth injury, or when vomiting is occurring. You can follow this method by reading the four steps in figure 4-17.

*Back-pressure-hiplift method*. This is another method of artificial respiration which may be used when injuries to the mouth prevent the use of other methods. It may also be used instead of the back-pressure-armlift method when the victim has injuries to the arm and shoulder part of the body. You can follow the steps for this method by referring to figure 4-18.

**Exercises (092):**

1. What are four methods of artifical resuscitation?

2. When giving mouth-to-mouth resuscitation to an individual, should anything be placed under his head? Why?

3. When giving resuscitation to an adult, why should the first three to four breaths be deep and given at a rapid rate?

4. What will cause the stomach to bulge when performing resuscitation?

5. How long will you continue artificial resuscitation without interruption?

6. Under what condition would you not be able to give mouth-to-mouth resuscitation?

7. What resuscitation method(s) can be used if the victim continues to vomit?

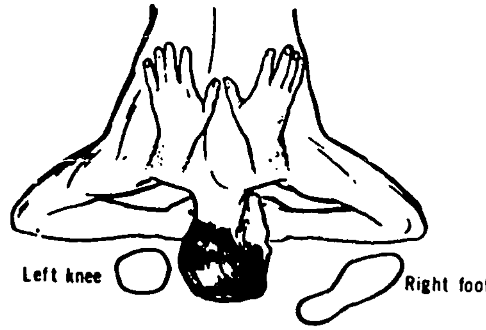
8. What resuscitation is used if mouth-to-mouth can't be given and the victim's shoulder is broken?

**093. List the steps and state the procedures pertaining to closed chest cardiac massage.**

Artificial respiration is to be applied whenever respiration has stopped but a pulse is felt, however slight. There may be times when respiration has stopped and no pulse is felt. In these cases, use closed chest cardiac massage along with artifical respiration.

**Closed Chest Cardiac (Heart) Massage.** This is the rhythmical compression of the heart without opening the chest by surgery. It is designed to provide an artificial circulation in order to keep blood flowing to the brain and other organs until the heart's beat has been reestablished. Closed chest cardiac massage is used in cases where the heart has stopped beating (no pulse can be detected). The primary reason for the heart's ceasing to beat is insufficient oxygen to the vital centers. This could result from smothering. Other reasons include electrical shock, excessive bleeding, shock, heart disease, effects of certain drugs, and even anxiety.

When the heart stops beating or breathing stops, it is always an emergency. Be calm; think; act! Time is of the



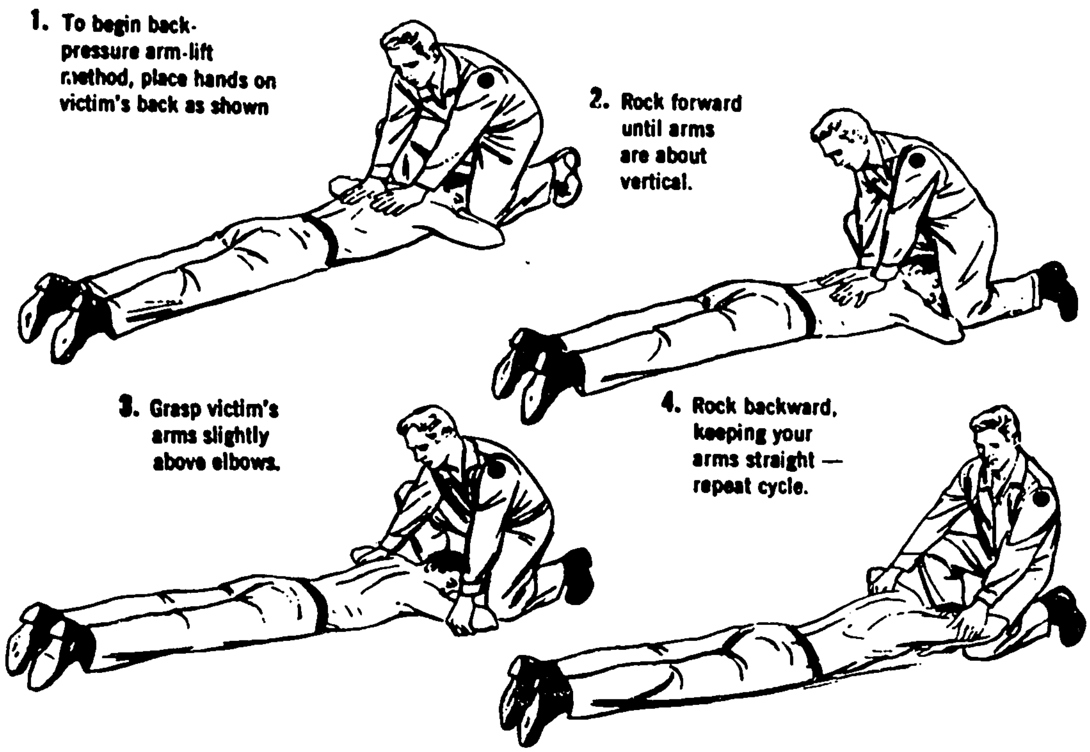




Figure 4–17. Back pressure—armlift method.

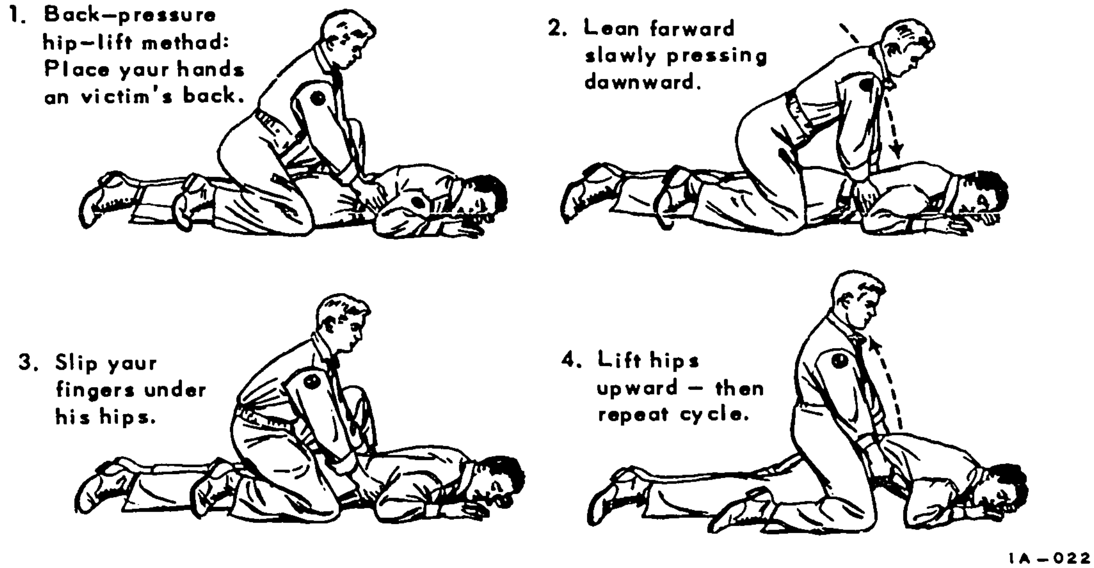



Figure 4–18. Back pressure—hiplift method.

utmost importance—SECONDS COUNT! If you are alone, or there are only two of you to conduct emergency aid, DO NOT TAKE THE TIME TO SEND FOR HELP. If additional personnel arrive, then send for medical personnel. The great danger when the heart or breathing stops is the lack of sufficient oxygen carried in the blood to feed the brain. The brain is the most sensitive tissue of the body, and the results of a shortage of oxygen become severe within a few minutes (usually about 3) after breathing and circulation are cut off. Thus, while a victim who has had delayed resuscitation may live, the person faces the possibility of extensive brain damage—a human vegetable.

*Procedures*. Use the following steps in closed chest cardiac massage:

(1) Evaluate the situation. Gently shake the victim to find out if everything is okay. If the victim does not respond, there may be a need for some type of first aid. Visually check the victim for some type of obvious injury. The chest may be crushed or there may be serious bleeding. For this objective we will assume there is no apparent injury to the victim. Included in this step, you should check the victim's vital signs. Check for breathing and for heart beat. The easiest place to check for a pulse is the neck. Place the tips of your fingers gently on the windpipe. Next, slide the fingers to the side near you, gently pressing the soft part of the neck next to the windpipe. This is shown in figure 4-19. 19.

(2) Position the victim. Lay the victim face up on a solid support, such as the floor, ground, or pavement. A bed or couch is too soft.

(3) Clear the victim's throat and mouth of any foreign matter.

(4) Begin mouth-to-mouth resuscitation simultaneously with heart massage. If two people are available, one gives mouth-to-mouth resuscitation while the other gives closed chest cardiac massage. Pay particular attention to the compression rate, positions of rescuers, and placement of hands.

(a) The compression rate for two rescuers is 60 per minute. This rate will maintain adequate blood flow and pressure and will allow cardiac refill. This rate can be maintained without fatiguing the rescuer. While one rescuer is doing this, the other rescuer starts the rescue breathing. The breathing rate is one breath for each 5 chest compressions. This rate is usually expressed 5:1, meaning 5 compressions to 1 breath. If only one person is available, alternate 15 compressions with 2 counts of mouth-to-mouth breathing. Because of the interruptions for lung inflation, the single rescuer must do each set of 15 chest compressions at a faster rate of 80 compressions per minute in order to achieve an actual compression rate of 60 per minute.

(b) If you are the one to do the compressions, kneel at right angles to the victim's trunk to best utilize your weight in applying pressure. Figure 4-20 shows the correct positions of two rescuers.

(c) To correctly place the hands, place the heel of the right hand on the breast bone of the victim, with fingers spread and raised so that pressure is only on the breastbone, but not on the ribs. Place your left hand on top of the right hand and press vertically downward. Apply enough pressure to depress the breast bone from 1½ to 2 inches (see fig. 4-21). The chest of an adult, although resistant when conscious, is suprisingly flexible when unconscious.

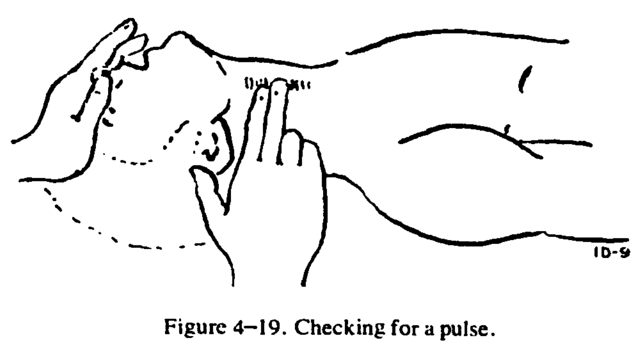



Figure 4–19. Checking for a pulse.

Figure 4–20. Two-person rescue position.

NOTE: With a child, use only one hand and relatively light pressure. In newborn infants, the use of fingers only may be sufficient.

Release the pressure immediately, lifting the hands slightly (see fig. 4-22), then repeat in a cadence of approximately 60 thrusts per minute.

(5) Continue steps. Continue closed chest cardiac massage until you get professional medical aid. Also, continue to give mouth-to-mouth resuscitation until help arrives. If you are on your own and the victim shows no response, continue both measures until the victim becomes stiff (rigor mortis sets in). Even trained and experienced medical personnel find it increasingly difficult to say when a person is really dead beyond recall. Again, the most important point is to immediately begin and continue resuscitation efforts.

*Precautions*. Care must be taken in administering closed chest cardiac massage. Follow the above procedures

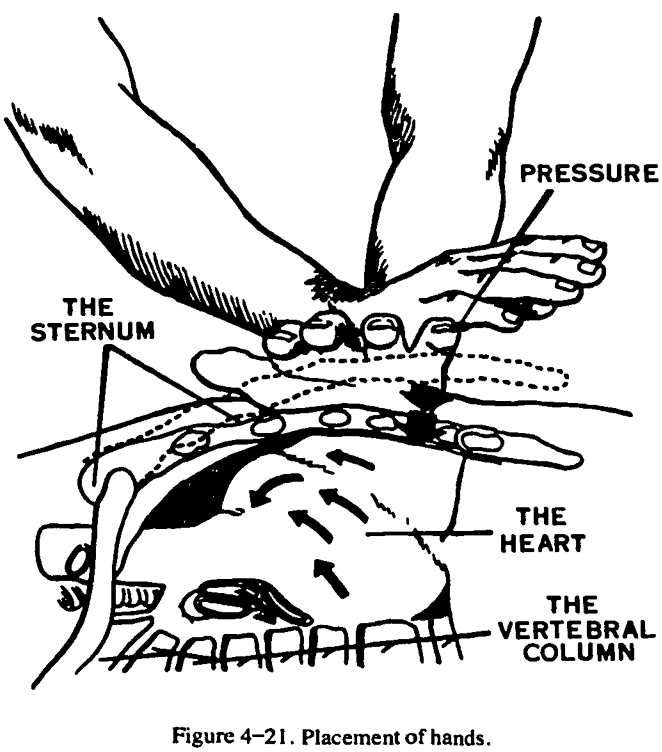



Figure 4–21. Placement of hands.

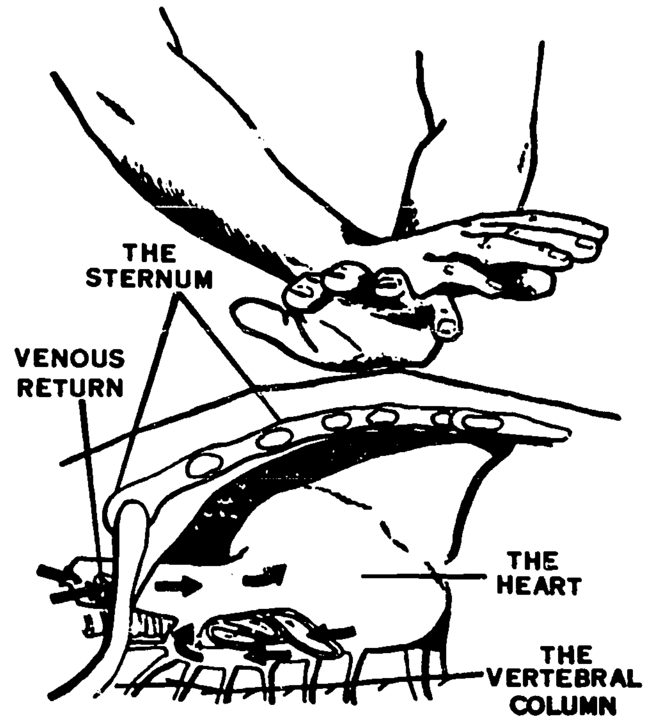



Figure 4–22. Releasing pressure.

carefully regarding the placement of hands and force applied in order to avoid complications, such as fractured ribs or injury to the spleen, liver, or other organs.

*Care of the patient*. An unconscious person becomes cold very rapidly, and chilling means a further strain on a vitality already weakened. Experience has shown that the cold to which the victims of gassing, electric shock, or drowning are often carelessly exposed is probably the most important cause of pneumonia. This disease is the most dangerous aftereffect of all these accidents. As far as possible, keep the patient covered and warm during and after resuscitation. Use hot pads, hot water bottles, hot bricks, radiant heaters, or other similar means; but remember that an unconscious person has no way of telling you when he or she is being burned. Do not permit exertion on the part of the victim. If it should be necessary to move the victim, keep the person lying down.

**Exercises (093):**

1. In brief statements list the 5 steps in closed chest cardiac massage.

2. Where is the easiest place to detect a pulse on an individual?

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3. If only one rescuer is available, what is the rate of compressions to one breath?

4. How long should you continue closed chest cardiac massage?

5. When giving closed chest cardiac massage to an individual, the rescuer exerts pressure at what rate?

6. What complication could result if you did not follow the correct procedure when performing closed chest cardiac massage?

7. Why is it necessary to keep the victim covered and warm during and after resuscitation?

**094. Identify particular blood vessels with their functions and procedures for controlling bleeding from lacerations and abrasions with their purpose.**

**Circulatory System.** In order to be able to stop or control bleeding, you must first understand something about how the blood circulates through the body. When blood leaves the heart, it is pumped into large vessels called arteries. As pressure from the heart drives the blood, it travels through smaller and smaller arteries, until it reaches the small blood vessels called the capillaries. After leaving the capillaries, the blood starts its trip back to the heart. The blood enters larger and larger vessels, called veins. It is the veins that return the blood back to the heart.

**Types of Bleeding.** Types of bleeding are classified by the type of blood vessel which has been cut. These types are called capillary, venous, and arterial bleeding. In capillary bleeding, the blood oozes or flows at a very slow rate. The blood is bluish-red and is easily controlled. The rate of flow in venous bleeding will depend on the size of the vein that has been cut. The rate of flow will be more steady and darker in hue than capillary blood. In arterial bleeding, the most dangerous type, there is a large amount of bright red blood. It spurts in rhythm with the heart beat and can usually be detected by a pumping action. Of course, the type of bleeding will influence the way you control the blood flow.

**Controlling the Blood Flow.** In attempting to control the flow of blood, there are a few steps that you should take immediately.

(1) Lay the victim down. If the victim does not lay down, faintness may occur at the sight of blood and further injury may occur.

(2) Expose the wound so that you can check the entire area affected by the cut.

(3) To stop the flow of blood you should apply pressure to the cut with a dressing or with some substitute such as an undershirt. Be sure to use a clean article if possible. Place the dressing against the cut and apply pressure. The pressure may be exerted by the use of the hand. Continue pressure as long as needed. If the cut is on the arms or legs, you may elevate the limb to help slow down the flow of blood. Do not raise the limb if you think the bone is broken. This could result in further injury. This procedure will usually control most severe bleeding of all types.

(4) If the above procedure does not work, you may be able to stop the flow of blood by applying hand or finger pressure at various points on the victim's body. The major pressure points are shown in figure 4-23. Each one of the dots in the figure is a major pressure point. The two most commonly used pressure points are the ones located in the groin and the inner side of the upper arm. Use the neck pressure point when the victim has a profusely bleeding scalp wound; however, use the neck pressure point only as a last resort—when all other methods of stopping the bleeding have failed. Do not apply pressure to both neck points at the same time. To do so would severely reduce the blood supply to the brain, causing unconsciousness and then death.

(5) If the bleeding has not been stopped by any of the steps so far listed, as a last step, use a tourniquet. A tourniquet could be defined as a wide band of cloth or some other similar material placed just above a wound to stop all flow of blood. Since the use of a tourniquet will stop all blood flow to the point of application, it should be used as a last resort only. Any time blood flow to a limb is stopped, you run the risk of losing that limb. As a last step, you may have to sacrifice a limb in order to save a life. Once a tourniquet is applied, you must insure that the victim receives care by a physician as soon as possible.

To use a tourniquet, place it just above the wound. If the wound is in a joint area or just below a joint, you should place the tourniquet right above the joint. Listed below are the steps to follow in applying a tourniquet.

*a*. Wrap the tourniquet band twice tightly around the limb and tie in a knot (see fig. 4-24,A).

*b*. Place a strong, short stick, or some similar object, on top of the knot. Tie two more knots on top of the stick (see fig. 4-24,B).

*c*. Twist the stick to tighten the tourniquet until the bleeding stops (see fig. 4-24,C).

*d*. Secure the stick in place with the loose ends of the tourniquet or another strip of cloth (see fig. 4-24,D).

*e*. Make a written note of the location of the tourniquet and the time it was applied. Attach this note to the victim's clothing.

*f*. Treat the victim for shock and also any other first aid he may require.

*g*. Never cover a tourniquet.

*h*. Do not loosen the tourniquet except on the advice of a physician.

Hopefully, you will never have to use any of these steps. But because of the dangers of your job, you could be in a

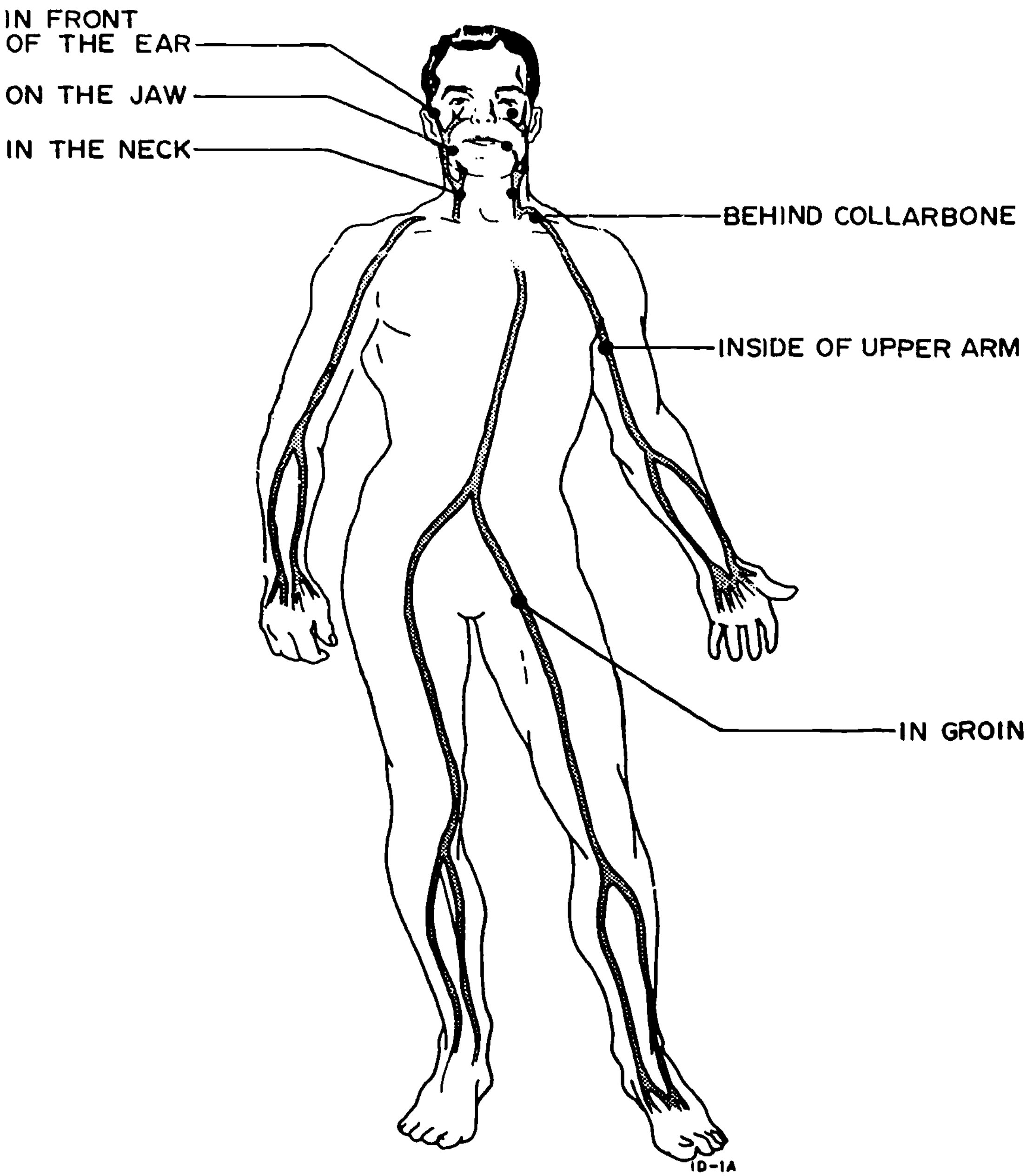


Figure 4-23. Body pressure points.

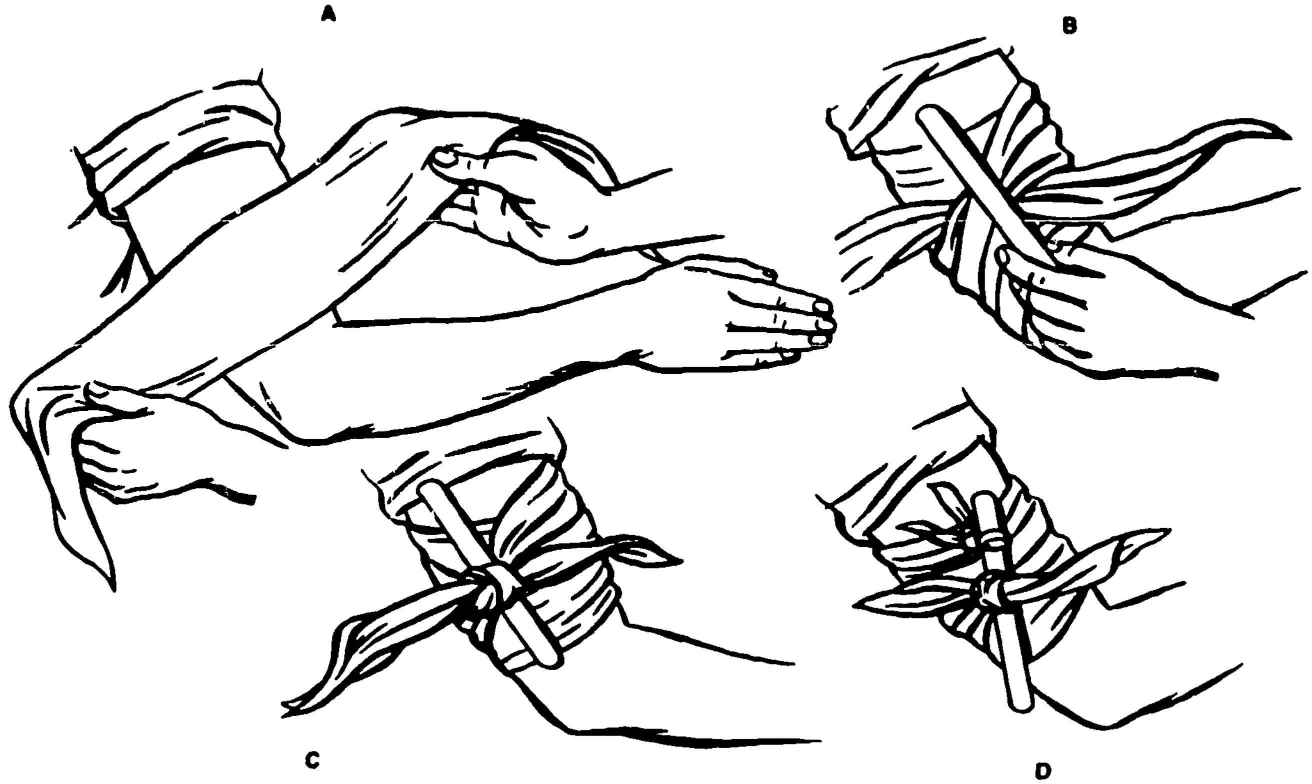


Figure 4–24. Tourniquet application.

situation where you need to know these steps. For this reason, you should study this section carefully to insure that you know what to do to control or stop the flow of blood from a cut or wound.

**Exercises (094):**

1. Match the type of blood vessel listed under column A, to the correct description under column B.

| *Column A* | *Column B* |
|---|---|
| ____ (1) Capillaries. | a. The blood leaves the heart though these blood vessels. |
| ____ (2) Veins. | b. The smallest blood vessels. |
| ____ (3) Arteries. | c. Blood is returned to the heart through these blood vessels. |

2. What is the purpose of elevating the arm or leg when trying to control the flow of blood?

3. What are the two most commonly used pressure points?

4. What is the last resort in trying to control the flow of blood from a cut?

5. Who can authorized a tourniquet to be loosened?

**095. State the procedures necessary to protect and treat specific types of wounds, and state purposes and precautions related to specified procedures.**

**Protecting the Wound.** In addition to stopping the flow of blood from a cut or wound, you should know how to protect the wound from infection and further injury. A dressing held in place by a bandage not only controls bleeding, but helps to protect the wound from harmful germs and foreign matter. It also helps to protect the wound from further injury. You should keep your hands off the wound when applying the dressing. Do not touch the side of the dressing that goes next to the wound. Do not attempt to cleanse a deep wound as this may cause bleeding to resume. Don't pull clothing over the wounded area; tear or cut clothing away from the wound instead.

**Treatment of Wounds.** A wound that is not bleeding severely and is not deeper than skin tissues should be cleaned before it is dressed and bandaged. Before you clean the wound you should wash your hands with soap and hot water, if possible. Wash in and around the wound to remove bacteria and foreign matter. Rinse the wound with clean water and blot the wound dry with a sterile gauze pad or clean cloth. Then apply a dry sterile or clean dressing and bandage it in place. Some wounds will require different first aid, depending on where the wound is.

*Chest wounds*. Chest wounds are particularly dangerous if air is being sucked in or blown out of the chest cavity through the wound. In this case, the wound itself is not as dangerous as the air which goes through it, because the air squeezes the lung, thus collapsing it.

Make the chest wound airtight as soon as possible. To do this, have the victim breathe out if possible. Then, put a dressing which is large enough to stop the flow of air through the wound; the dressing should more than cover it. Pack the dressing firmly over the wound and cover with a large piece of material, such as from a waterproof garment, to help make the wound airtight. Bind this covering with a belt or strips of torn clothing. As in all cases of severe injury, treat for shock.

*Belly wounds*. To treat a belly wound, cover it with a sterile dressing from a first aid pack or kit. Do not try to replace organs, such as intestines, protruding from the body. To do so might cause infection and severe shock. However, if you must move an exposed intestine in order to cover the wound, do so. Be sure to keep the intestines wet with water.

Don't give the victim food or water through the mouth; the food could pass out through the intestines and might spread germs in the belly. Treat for shock.

*Neck wounds*. Neck wounds are serious because of the many blood vessels in that area. Stop the bleeding by exerting pressure with a sterile dressing. Then bind the dressing to protect the wound.

If a large artery, a vein, or both are cut, apply hand pressure both above and below the cut. Continue the pressure until a medical officer directs that the pressure be released. In such lifesaving situations, you need not worry about getting your hand in the wound. A folded cloth or pad of clean material under your fingers may be a great help since the blood could make the neck slippery to hold.

A victim with a penetrating neck wound needs special treatment to prevent choking on blood. Have the victim lean forward with the head held forward and down or have the victim lie face down. These positions will allow the blood to drain out of the mouth instead of down into the windpipe. Remember to treat for shock, but do not use a face-up position.

*Jaw wounds*. Have the victim sit up with the head held forward and down, or have the victim lie face down. If the jaw is broken, do not bandage the mouth tightly shut. Place the absorbent part of the dressing over the wound and tie the tails over the top of the head to lend support to the jaw. An additional dressing may be used to tie under the chin for more support, but remember to allow enough freedom for free drainage from the mouth. When treating a jaw wound, as in the case of a neck wound, do not use a face-up position.

*Head wounds*. A head wound may consist of any one of the following conditions or a combination of these conditions: a cut or bruise of the scalp, fracture of the skull, an injury to the brain, or injury to the blood vessels of the scalp, skull, and brain.

A scalp wound is easily detected because of the large amount of bleeding. To treat such a wound, follow the steps already covered for controlling the bleeding.

It is more difficult to discover whether there is an internal injury to the head. The best step you can take with a victim with a head wound is to get to a medical facility for treatment as soon as possible. A victim with a head wound should be treated for shock.

**Exercises (095):**

1. Why should you not cleanse a deep wound?

2. What is so dangerous about chest wounds?

3. Why should you not replace organs, such as intestines, from a belly wound?

4. Why are neck wounds serious?

5. What first aid steps would you take for a person with a neck wound?

**096. Specify the symptoms and treatment of heat exhaustion.**

When you are exposed to extreme heat for an extended period of time, you should take special precautions to protect yourself.

**Heat Exhaustion.** Heat exhaustion is caused when the body sweats and more body fluids are lost than the body is taking in. If you are suffering from heat exhaustion you will show signs of fatigue. You may feel weak, nauseated, or dizzy, you may even faint.

Most of the time, our body temperature will be kept at a steady or stable state. This is done by the evaporation of sweat and by the way air circulates or moves around the body. In cases where the body becomes overheated and is not able to get rid of the excess heat, serious effects could occur. Also, if you sweat a lot and do not put liquids back into your body, you stand a high chance of suffering from heat exhaustion. This is especially true when work is done under strenuous circumstances and hot temperatures

*Symptoms of heat exhaustion*. If you or your coworkers are suffering from heat exhaustion you or your coworkers may show any or all of the following symptoms:

- Skin may be pale, cool, and clammy.
- Pulse may be weak and rapid.
- Pupils may be dilated.
- Body will be sweating a lot.
- Body temperature may be normal or right at normal.
- May feel dizziness or weakness.
- May vomit.

*Treatment of heat exhaustion.* First aid for heat exhaustion includes the following steps:

(1) Call or send for a doctor as soon as possible.
(2) Move the victim to a cool place.
(3) Have the victim lie down with head low.
(4) Elevate feet approximately 10 inches.
(5) Loosen clothing.
(6) Give the victim sips of salt water—if conscious.
(7) Cool the victim with a wet cloth. If you can't do this, fan the victim. Don't cool too fast or serious side effects could result such as pneumonia.
(8) Do not give the victim fluids if vomiting.
(9) The victim should not return to work for a couple of days. During this period the victim should stay away from exposure to abnormally warm temperatures.

**Exercises (096):**

1. From the following list of statements, place an "X" in the blank provided if the statement is a symptom or treatment of heat exhaustion and if it is not correct the statement.

a. ____ The victim's clothing should be loosened.
b. ____ Place the victim in a tub of cold water.
c. ____ The body temperature is usually quite high.
d. ____ Give the victim sips of salt water.
e. ____ If the victim feels OK, let the victim return to work immediately.
f. ____ The victim's pulse may be weak and rapid.
g. ____ The victim may faint.
h. ____ The victim will probably be sweating a lot.
i. ____ The victim's pupils will be contracted.

**097. State causes, definition, and time for treatment for shock and identify particular first aid procedures with their purposes.**

Although this objective on shock is being covered last, treatment for shock is very important. Remember, you should treat a victim for shock, regardless of the type of injury. Treatment for shock should be started at the same time you start the first aid for the victim.

**Shock.** Shock is a condition of great weakness of the body. It can, and often does, result in death. Shock can be caused by any kind of injury. Loss of blood, crushed bones, bone fractures, burns, bullet wounds, and other injuries may cause shock. The more severe the injury, the more likely the occurrence of shock.

A person in shock may tremble and appear nervous. The pulse becomes rapid and weak. The person may be excessively thirsty, get quite pale and wet with sweat, gasp for air, and may lose consciousness.

Shock may not appear for some time after an injury. Treat a victim for shock whether or not symptoms of shock are present. Your efforts will have a greater chance of being effective if you treat the victim for shock before the victim has a chance to suffer from it.

**Treatment of Shock.** You can start the treatment of shock by keeping calm. A calm behavior on your part will reassure the victim. If the victim has been wounded or cut, keep the victim from seeing the cut or wound. By doing this, you lessen the chances of the victim falling into a state of severe shock.

You should make the victim as comfortable as possible. Remove any bulky items, loosen belt and clothing. Handle the victim gently; do not move the victim more than absolutely necessary. If the victim is lying in an abnormal position, make sure no bones are broken before you straighten the victim out.

Use a blanket, coat, poncho, etc., to keep the victim from becoming chilled or cold. Be sure to put something under the victim to protect from the cold ground.

If the victim has lost consciousness, place the victim face down with the head turned to one side. This will help to prevent choking, should the victim vomit. Once you have the victim in this position, do not move the victim. To do so may cause the blood pressure to drop.

If the victim is conscious, replace body fluids by administering coffee, cocoa, or tea to drink. Do not give fluids to victims who are unconscious or have belly wounds.

If oxygen is available, give it to the victim.

Briefly, the treatment for shock is as follows:

- Reassure the patient and make as comfortable as possible by removing bulky items and by loosening clothes.
- Move the patient as little as possible; handle gently.
- Make sure there are no broken bones before straightening the patient out.
- Keep the patient warm.
- If the patient is not conscious, place face down with the head turned to one side.
- If conscious, give the patient fluid, such as coffee, tea, or cocoa.
- Give the patient oxygen if it is available.

**Exercises (097):**

1. In a brief statement write the definition of shock.

2. Why should you keep the victim from seeing the cut or wound?

3. Why should an unconscious victim be placed face down with the head turned to one side?

4. Why should you not move a victim once you have the victim in a shock position?

5. When should treatment of shock be started?

6. Name two types of injury that could cause shock.

7. Can shock be caused by any type of injury?

# ANSWERS FOR EXERCISES

**Reference:**

CHAPTER 1

001 – 1. a. ___.
b. X.
c. ___.
d. ___.
e. ___.
f. X.

002 – 1. a. Mechanical.
b. Civil Engineer.
c. Resources and Requirements.
d. Electrical.
e. Operations.
f. Operations.
g. Operations.
h. Electrical.
i. Operations.
j. Family Housing Management.

003 – 1. (1) d.
(2) h.
(3) e.
(4) i.
(5) f.
(6) b.
(7) a.
(8) g.
(9) d.
(10) c.

004 – 1. They participate in the real property operation and maintenance CE work force.

004 – 2. In the 60's the emphasis was on a nuclear war, whereas, in the 70's the plan was based on a conventional war.

004 – 3. A larger mobility team was required and the civilian work force was responsible for stateside operations during wartime conditions.

004 – 4. (1) To give direct combat support roles in support of the Air Force's worldwide mission.
(2) To provide a mobile rapid response capability for recovery of all base facilities following wartime and natural disaster.

004 – 5. The augmented unit.

004 – 6. 28 hours.

004 – 7. The Structural/Pavements (55) career field.

004 – 8. A total of four electricians are on the CF–2 team; one 3 level, two 5 levels, and one 7 level.

004 – 9. Each team member is issued a mobility toolkit for his or her career field as listed in Attachment 1 of 93–3.

004 – 10. The M–16 rifle or .38 caliber revolver.

005 – 1. From trained personnel from all major commands.

005 – 2. RED HORSE Squadrons provide heavy equipment repair and construction of troop facilities.

005 – 3. a. CES-1.
b. CES-2.
c. CES-3.
d. CES-3.
e. CES-2.
f. CES-1.

006 – 1. a. 99000, E1
b. 54210.
c. 54230.
d. 54250.
e. 54270.
f. 54299.
g. 54200.

006 – 2. E–5.

006 – 3. Electrician, electrical power lineman, or electrical power production.

006 – 4. Plans, directs, coordinates, implements, and controls base electrical service.

007 – 1. a. X.
b. X.
c. ___.
d. X.
e. ___.
f. ___.
g. X.
h. X.
i. X.
j. ___.

008 – 1. To follow and comply with sound security practices, to be familiar with the regulations and instructions, to protect all classified information you possess, and to make sure you don't cause others to violate security policies.

008 – 2. a. All persons must understand the purpose and principles of the information security program and their responsibilities for protecting information.
b. All persons must be informed of the regulations and supplemental instructions that apply to them.
c. All supervisors are responsible for being sure their people follow the rules.
d. Supervisors should conduct their orientation briefings as part of their normal duties.

009 – 1. a. True.
b. True.
c. False. Change "unclassified" to "classified."
d. True.
e. False. Change "Secret" to "For Official Use Only."
f. True.

010 – 1. Information the disclosure of which could cause *exceptionally grave damage* to national defense.

010 – 2. Information the disclosure of which could cause *serious damage* to national defense.

010 – 3. Information the disclosure of which could cause *identifiable damage* to national defense.

010 – 4. (1) b.
(2) c.
(3) a.
(4) a.
(5) b.

011 – 1. a. No. Sgt Jones should have spoken to someone who knew what Blue Knight was or used secure communications to discuss the project.
b. Yes.
c. Yes.
d. Yes.

012 – 1. Telephone off the hook, unplanned conversations, attempting to disguise information, homemade codes, and ciphers.

012 – 2. Unplanned conversations.

012 – 3. Disguising the information or using homemade codes or ciphers.

013 – 1. When an enemy knows in advance he is going to be attacked, he has time to plan his counteractions or avoid that attack.

013 – 2. The purpose is to keep the tactical and strategic advantage on our side by protecting information and activity regarding our plans.

014 – 1. (a) Identify those portions of an operation that require protection, (b) develop OPSEC procedures and techniques, (c) systematically assess OPSEC status at all operational levels, and (d) document deficiencies and institute corrective actions.

014 – 2. Operations, communications, and procedures.

014 – 3. Any type of information that could reflect a change in procedure or operations, whether the information seems important or unimportant.

015 – 1. a. Yes. This is a routine community relations effort, usually screened and cleared by the Office of Information.
b. No. This conversation deals with a probable limitation on a strategic weapon system component.
c. No. This conversation deals with the distances to the location of strategic weapons systems components from a known point.
d. Yes. This is a routine story for acknowledging excellence.
e. No. This also appears to be a probable compromise of classified material, since the "(S)" indicates Secret classification.
f. No. This information reveals a probable change in some part of the missile system, thus pointing toward other changes.

016 – 1. (1) a.
(2) b.
(3) c.
(4) a.
(5) b.
(6) c.
(7) a.
(8) b.
(9) c.
(10) a.
(11) c.
(12) c.

017 – 1. (1) a, b, d, h.
(2) c, e, f, g.
(3) b.
(4) c.
(5) h.
(6) e.
(7) d.
(8) g.
(9) f.
(10) a.
(11) f.
(12) g.
(13) c.
(14) h.
(15) a.
(16) d.
(17) b.
(18) g.
(19) h.
(20) a.

018 – 1. (1) a, (2) b, (3) d, (4) c, (5) e, (6) a, (7) c, (8) e, (9) b, (10) d, (11) b, (12) a, (13) b, (14) e, (15) c, (16) d, (17) b.

019 – 1. They are identified by having the TO number placed on them and they should be dated. In some cases, a one-sheet identifying TO is issued as a title sheet.

019 – 2. They may be in the regular TO binders in numerical order with the other TOs or they may be filed in a separate file in numerical order. When in the regular TO file, the identifying title sheet is filed just in front of the publication. If kept in a separate file, the identifying title sheet is filed in numerical order and a notation in put on it to show where the publication is filed.

019 – 3. They are listed in the proper numerical index in numerical order.

019 – 4. (1) Some items are bought locally off the shelf and (2) some items are bought in very small quantities.

019 – 5. Specialized instructions, standards, and codes.

019 – 6. Through local procurement from the equipment manufacturer or from other commercial sources depending on the publication.

019 – 7. They are not indexed in the publications indexes but they should be kept together and filed in a section or on a shelf of a publications filing cabinet.

020 – 1. a. __, b. X, c. __, d. __, e. X, f. X, g. X. h. __, i. __, j. X.

020 – 2. a. F, they are issued as regulations; b. T; c. T; d. F, they are listed in numerical order; e. T; f. F, they are listed generally in the order they were issued; g. F, it contains only the general subject areas; h. T.

020 – 3. (1) g, (2) i, (3) f, (4) a, (5) b, (6) e, (7) b, (8) k, (9) f, (10) b, (11) k, (12) d.

020 – 4. In TO index 0–2–01 (NI&RT).

020 – 5. Electric drill press - category 34.
Oxygen cylinder - category 42.

020 – 6. Numerical index TOs begin with 0–1.

020 – 7. TO 0–2–1.

020 – 8. TOs are identified by category numbers and are indexed numerically, alphabetically, cross referenced, and by specific equipment.

020 – 9. 0–1–01.

020 – 10. The numbers of the first and last TOs in the binder are shown on a tab located on each binder.

020 – 11. TOs are filed in numerical order and, when alphabetical letters are involved, both numerically and alphabetically.

021 – 1. AFR 85–1, AFM 85–3, AFM 85–5, AFR 85–7, AFR 85–10, AFM 85–14.

021 – 2. AFP 85–1, AFR 85–9, AFM 85–13.

022 – 1. a. X.
b. ___.
c. ___.
d. X.
e. X.

023 – 1. (1) b.
(2) a.
(3) a.
(4) c.
(5) a.
(6) a.
(7) c.
(8) c.
(9) b.
(10) a.
(11) c.
(12) b.

024 – 1. Standard publications are filed in binders in numerical sequence by series number and specific item number. The binders are numbered and placed in the file in numerical sequence.

024 – 2. Changes are filed immediately behind the basic publication affected. Supplements are filed behind changes in descending order according to the level of command that published the supplement.

024 – 3. Binder 4.

024 – 4. Identify the number of the needed publication, check current status of the publication, and look at the binder inserts until you find the number on an insert or it falls between the numbers on an insert—your publication is in that binder.

024 – 5. First use TO 0–1–01 to find the proper category index number. Second, get the binder with the category index in it and look at the table of contents to find proper subcateogry for the type of tool you are looking up. Turn to the subcategory indicated and find the correct TO number. Then, look for the binder that contains the wanted TO, remove it from the file, and turn to the TO.

024 – 6. Binder 68.

025 – 1. Subjects in standard publications can be found in the table of contents or the index.
025 – 2. The index provides specific information whereas the table of contents contains general information.
025 – 3. (a) Locate the desired publication, (b) use the table of contents or the index and locate the wanted subject, (c) turn to the indicated page or paragraph, and (d) research the material for the desired information.

CHAPTER 2

026 – 1. A work plan that identifies work ahead of time.
026 – 2. The planners perform an inspection of base facilities to find out what work needs to be done.
026 – 3. a. Recurring labor such as cathodic protection readings.
b. Equipment maintenance such as fire alarms.
026 – 4. Management by exception is the process of comparing estimated labor hours to actual labor hours.
026 – 5. Base Engineer Automated Management System (BEAMS).

027 – 1. A maintenance program that automatically schedules, through BEAMS, recurring work to the shops.
027 – 2. Shop supervisors will fill out an AF Form 1841, Maintenance Action Sheet (MAS) for each month.
027 – 3. Superintendents will review the RMPs to make sure only essential work is included.
027 – 4. Any of the following:
a. Calibrating thermostats on deep-fat fryers.
b. Maintaining emergency lights.
c. Reading static grounds.
d. Reading lightning protection.
e. Cathodic protection maintenance.
f. Fire alarm maintenance.
g. Intrustion alarm maintenance.

028 – 1. a. Uniform reporting system.
b. Identifies direct labor cost against work orders.
028 – 2. a. ATA.
b. ETA.

029 – 1. The controller or shop supervisor fills this form out on a daily basis to record man-hours used.
029 – 2. They are printed below the respective group, military or civilian.
029 – 3. The control center code and cost center code.
029 – 4. The daily work sheet is based on AF Form 561.
029 – 5. A current job is assigned to that worker.
029 – 6. The man-hours are entered by numbers assigned to the jobs each person performs.

030 – 1. It is used to compute labor cost through BEAMS on a monthly basis.
030 – 2. Only labor loaned from ETA to ATA cost centers and family housing management.
030 – 3. Work control, planning, real estate management, cost accounting, engineering, and others like these.

031 – 1. a. An emergency work order from the service call desk.
b. A routine job order on AF Form 1879.
c. AF Form 327, BCE Work Order.
d. AF Form 1219, BCE Multi-Craft Job Order.
031 – 2. The shop supervisor.
031 – 3. The objective is to know the location of each worker and the status of all work.

032 – 1. (1) c.
(2) f.
(3) d.
(4) e.
(5) a.
(6) f.
(7) e.
(8) e.
(9) d.
(10) b.
(11) c.
(12) e.

033 – 1. Unit mission, number of people.
033 – 2. The table of allowance (TA).
033 – 3. The average AF unit.
033 – 4. TA–001 or MEMI.
033 – 5. 486.

034 – 1. The chief of supply.
034 – 2. To make sure all items are there and serviceable.
034 – 3. AF Form 126 is used to record all custodial requests.
034 – 4. The new custodian must attend the equipment custodian briefing and make sure all discrepancies are cleared up before signing for the account.
034 – 5. AF Form 601b is used to ask for allowance and authorization changes, ordering, turn-ins, and updating equipment.
034 – 6. TA–016.

035 – 1. Material Control.
035 – 2. Service call and your controller.
035 – 3. To make sure all items are there and correct.

036 – 1. Bench stock.
036 – 2. 30-day.
036 – 3. Material Control.
036 – 4. Bench stock code (always B).

037 – 1. (1) a.
(2) a.
(3) b.
(4) a.
(5) b.
(6) b.
(7) a.

038 – 1. Yellow.
038 – 2. Unserviceable but repairable.

039 – 1. AF Form 1801, Request for Issue or Turn-in, is used for expendable shop use type items.
039 – 2. The items are recurring issue.
039 – 3. The justification.

040 – 1. For temporary custody of an item.
040 – 2. Normally 24 hours, but does stay in effect until returned.
040 – 3. The form is returned to the individual.

041 – 1. All personnel.
041 – 2. TO 00–35D–54, USAF Material Deficiency Reporting System or AFR 66–30, Product Improvement Program for Operational Equipment.

CHAPTER 3

042 – 1. a. To the mission.
b. Tell them the job comes first. As soon as the job is complete, they can have the time off.
042 – 2. Explain the situation to Sgt Sims and express regret in not being able to let him off at this time, because the mission must come first.
042 – 3. Explain to the colonel that you have a work schedule you have to go by and ask him to call the service call desk to get a work order.
042 – 4. Inform Material Control of the problem and turn them in for repair.
042 – 5. You will get the tools and equipment they will need, train them on shop tools and equipment, and provide on-the-job training necessary for upgrade training.

043 – 1. Job proficiency is knowing the 542X0 specialty principles and performing the skills.
043 – 2. a. Personnel probably would not respect you as a supervisor.
b. The product from your shop would probably be of marginal quality.

044 – 1. a. You explain to the worker that you are unfamiliar with that particular item of equipment but that you both can look it up in the TO or manual.
b. You make it known that your door is open to anyone that has a problem and wants to talk it over with you.

c. You treat her as you would her male counterparts, i.e., find out what her capabilities are and assign her jobs accordingly.
d. You do not say anything to anybody else.
e. You begin to assign them some of your responsibilities.
f. You stay around to hear what they have to say about the job but excuse yourself when they start discussing the party.
g. Counsel with the Airman and explain to him the consequences of his actions.
h. Call your workers together and explain the importance of the mission and how they must work together to accomplish their goals.
i. You set up a policy that if the workload permits you give the people that may have had to work on the weekend time off that next week.
j. You go to the commander and explain that the power had to be cut for the safety of your workers and that Sgt Morgan had the best interest of all concerned in mind.

045 – 1. Your list should include information from the list below.
Name:
Marital Status:
Age:
Education/Experience and their special talents:
Background: Find out the locality the worker is from
Housing: FInd out where your worker is living.

045 – 2. Your outline should include (for example):
Functions/Organizational Structure.
Their Position.
Chain of Command.
Duties and Responsibilities.
Career Development.
New Duties to Learn.
Work Standards.
Shop Procedures and Policies.

046 – 1. Mission essential work.
046 – 2. Work that duplicates work done somewhere else or does not contribute to the mission.
046 – 3. The lower ranking, unskilled workers in your shop.
046 – 4. They will do less work, of poorer quality, and cause more accidents.
046 – 5. It is easier to increase the worker's skills.
046 – 6. a. Only one person is responsible.
b One worker can be more efficient.
046 – 7. Worker morale will decrease, accidents may increase, and some workers may be tempted to "goof off."

047 – 1. a. b.
b. a.
c. c.
d. d.

048 – 1. Many times, directions given mean one thing to the supervisor and something different to the workers.
048 – 2. By having your workers repeat your directions back to you.
048 – 3. From regulations, manuals, and operating instructions.
048 – 4. Organizational objectives and good judgment.
048 – 5. a. Request.
b. Implied or suggested.
c. Demand.
d. Request for volunteers.
e. Implied.
f. Request.
048 – 6. Long, complicated instructions should be put in writing.
048 – 7. You may need to explain the situation, provide a chance for questions, or be sure that directions are understood.
048 – 8. You must answer the question of what, why, when, where, who, and how.
048 – 9. Terms may be too technical, directions may be vague, not enough information is included, directions are too long or complicated, the arrangement may not be logical, the work may seem unduly complicated, and directions may not be practical.
048 – 10. If the person giving directions shows a poor or "don't care" attitude, workers are going to do the job the same way.
048 – 11. Keeps workers from getting bored, spreads the less desirable jobs around among the workers, is an important part of upgrade training, and provides skilled workers to cover essential jobs when some people are gone.

049 – 1. a. B.
b. G.
c. G.
d. B.
e. B.
f. B.
g. G.
h. G.
i. G.
j. B.
k. G.
l. B.
m. G.

050 – 1. a. Get mad.
b. Ignore the problem.
c. Blame someone else for it.
d. Run away to the bar or club.
e. Stall—don't make any decision—maybe the problem will go away.
f. Avoid the problem by retreating into food, alcohol, or drugs to escape.
050 – 2. (1) b. b.
(2) a.
(3) c.
(4) b.
(5) e.
(6) c.
(7) d.
(8) b.
(9) a.
(10) c.
(11) b.
(12) e.

051 – 1. a. Motivation.
b. Understanding.
c. Responsibility.
d. Directivity.
e. Productivity.
f. Satisfaction.
051 – 2. False. Because a chewing out causes anger and resentment. Counseling builds up the self image.
051 – 3. a. X.
b.
c. X.
d. X.
e.
f. X.

052 – 1. a. T.
b. T.
c. F.
d. T.
e. T.

052 – 2. Your answer should be somewhat like this.
a. Collect information.
b. Select a quiet place for an interview.
c. Prepare yourself for the interview.
d. Start interview by establishing rapport.
e. Tell him why he was called.
f. Listen to him.
g. Find the real problem.
h. Outline a course of action.
i. Record the interview and follow up.

053 – 1. Performance standards define the quality and quantity of work that must be put into a job for it to be satisfactorily completed.
053 – 2. Do not include too much operating details in the standard and keep the standards reasonable.

053 – 3. Worker morale drops, personnel turnover increases, production drops off, accidents and errors increase, and workers become overly fatigued.
053 – 4. Workers get bored, mischief and horseplay goes up, workers have more grievances, and absenteeism increases.
053 – 5. Performance level should be set so it can be reached by any qualified, competent worker.
053 – 6. If the present worker is exceptional, the standard will be too high. On the other hand, if the worker is below average, the standard will be too low.
053 – 7. You must determine what is a reasonable range of performance to be acceptable. Those that are below the range may be unacceptable and those that are above the range are probably outstanding.
053 – 8. In addition to your opinion, you should get the opinions of workers doing the job and of other supervisors, especially those that have similar operations.
053 – 9. You must use them. Check your people's performance against the standards and discuss your observations with them. Give recognition to the good workers and help workers who do not meet the standards by training or other means, and try to motivate adequate workers to do better if they are capable.
053 – 10. They set minimum acceptable production goals for each worker; they tend to create job satisfaction; they provide a basis for estimating future work capacity; they provide data for planning, organizing, and assigning work; they help determine who needs training; and they provide a basis for personnel actions and formal ratings.

054 – 1. They must be careful to keep tempers from getting out of hand, prevent unkind remarks, and prevent a breakdown of good working relationships.
054 – 2. By making sure they understand the performance CDC54250 standards expected of them.
054 – 3. Observation, evaluation, and reporting.
054 – 4. Observation of performance should be made over an extended period of time and often enough to be sure the performance observed is typical. Observations should include the person's behavior, performance of duty, and work quality.
054 – 5. Isolated observations seldom show what the worker does normally. As a result, you may overrate or underrate the person rather than on representative behavior which would tend to reward or penalize the person unfairly.
054 – 6. The immediate supervisor of the airman.
054 – 7. When it is a referral APR.
054 – 8. Normally once a year or when a change of rating official is made.
054 – 9. A referral APR.
054 – 10. The APR will be an 8.

055 – 1. a. 909.
b. 911.
c. 909.
d. 910.
e. 77.
055 – 2. Entries are made by printing or legibly writing in black or dark blue ink.
055 – 3. The entire APR must be redone.
055 – 4. Erase the incorrect letters and insert the correct ones.

056 – 1. An evaluation device.
056 – 2. Annually, unless circumstances require a change.
056 – 3. The unit mission.
056 – 4. Critical and noncritical.
056 – 5. Critical.
056 – 6. Part three.

057 – 1. All organizations assigned enlisted personnel.
057 – 2. To train its enlisted personnel and qualify them in the knowledge and job proficiency needed to perform duty in an AFS.
057 – 3. All Air Force commands and some schools of the Army, Navy, and other Government agencies.
057 – 4. Headquarters USAF, Director of Personnel Programs.
057 – 5. Job proficiency and job experience.
057 – 6. Formal resident courses, CDCs, OJT, and SKTs.
057 – 7. Formal training.
057 – 8. To plan, conduct, and evaluate OJT.
057 – 9. OJT is a planned training program designed to qualify airmen, through self-study and supervised instruction, to perform in a given AFS while actually working in a duty assignment of their AFS.
057 – 10. Both training in approved courses and training on the job.

058 – 1. To train personnel to perform their assigned duties.
058 – 2. In the actual work situation.
058 – 3. Self-study and performance on the job under supervision.
058 – 4. The unit's mission.
058 – 5. To assist in developing a trainee's job proficiency.
058 – 6. The airman's current duty assignment.
058 – 7. The airman's immediate supervisor.
058 – 8. In the JPG.

059 – 1. a. Upgrade training (UGT) is conducted for the purpose of upgrading an airman's AFSC skill level in his or her AFSC.
b. Qualification training is conducted to increase an airman's knowledge and skill within an assigned position, during the time he or she is not on UGT, and training which does not result in the award of an AFSC.
c. Retraining is designed to qualify an airman for the award of an AFS or AFS shredout not in the normal progression pattern of a currently awarded AFS.
059 – 2. Through on-the-job training.
059 – 3. Because of changing Air Force concepts, requirements, equipment, and unit missions.
059 – 4. Yes.
059 – 5. OJT is a dual-channel training concept. Career knowledge training is still a requirement.
059 – 6. Yes. There is always a need for increasing the quality or quantity of production, indoctrinating personnel in new techniques or procedures, or qualifying technicians to maintain new equipment.
059 – 7. a. AFR 39–1.
b. AFR 39–4.

060 – 1. b, f, h, j.
060 – 2. c, e, g.
060 – 3. a, d, i.

061 – 1. (1) c, (2) d, (3) j, (4) b, (5) a, (6) d, (7) i, (8) g, (9) f, (10) a, (11) h, (12) c, (13) e, (14) f.
061 – 2. The trainee learns by doing while performing under the trainer's watchful eye in a productive capacity.
061 – 3. Through lecture and discussion, a trainer can impart information and discover what trainees already know. Through demonstration the trainer can show the safe and correct way to perform a task. Through performance under supervision the trainees can practice until they become proficient at the task.
061 – 4. Step 1, Prepare the training situation. Trainer's and instructor's activity almost identical—the trainer prepares the working environments; the instructor prepares the classroom.
Step 2, Prepare the trainee to receive job instruction. Again, the activities are almost identical. The trainer must discover what the trainees already know, but the instructor usually has this information before meeting the class.
Step 3. Present the operation to the trainee. All activities identical whether the trainer is teaching skills or the instructor is teaching attitudes.
Step 4. Try out performance. This step for the trainer compares with the evaluation step by the instructor.
Step 5. Follow up. This step by the trainer compares best with the measurement step by the instructor in the classroom. Of course, the instructor cannot put the students in a job situation.

062 – 1. Because of their complexity.
062 – 2. To divide a big job into easy, progressive, and teachable units.
062 – 3. The past experience and the learning capability of the trainee.
062 – 4. "Important Steps" and "Key Points."
062 – 5. To discover how you can best help the trainee to perform each operation safely, easily, correctly, and quickly.
062 – 6. The trainer.
062 – 7. The immediate supervisor.

063 – 1. A CDC or STS training reference for the AFSC.
063 – 2. A person capable of administering job proficiency training.
063 – 3. The supervisor can certify job proficiency on the task if he or she observes the performance and can verify it by an authoritative reference (e.g., TO or manual).
063 – 4. Proper procedures, tools, materials, etc, are used and the completed work meets established standards.
063 – 5. The Chief, Personnel Division, must appoint a competent authority who possesses all the facts. This authority carefully weighs all factors to decide if a capability exists.
063 – 6. The Chief, Personnel Division, forwards a statement of circumstances to the parent major command (MAJCOM).
063 – 7. The MAJCOM.

064 – 1. a. Technological advancements.
b. Personnel changes.
c. Career field adjustments.
064 – 2. By applying a plan of evaluation.
064 – 3. Current and projected training requirements.
064 – 4. Specialty description, STS, JPG and job breakdown, and the job performance requirements.

065 – 1. How seriously the people in the program accept their responsibilities.
065 – 2. a. STS.
b. Current JPG.
c. Task breakdown.
d. Necessary tools, equipment, and supplies.
065 – 3. Trainee participation.
065 – 4. Written.
065 – 5. Performance.

066 – 1. a. Formal courses.
b. Career Development Courses.
066 – 2. a. Ability of recent graduates to perform tasks to the specified training standard.
b. Extent to which acquired skills are used by recent graduates.
c. Extent to which knowledge is retained by recent graduates.
d. Need to revise STS, formal courses or CDCs.
e. Need for further evaluation of training problem areas identified by this evaluation of recent graduates.

067 – 1. The official Air Force specification for training.
067 – 2. Tasks, knowledges, and study/technical references.
067 – 3. 3, 5, and 7 skill levels.
067 – 4. The career development channel of OJT.

068 – 1. g.
068 – 2. i.
068 – 3. c.
068 – 4. m.
068 – 5. f.
068 – 6. n.
068 – 7. b.
068 – 8. j.
068 – 9. e.
068 – 10. l.
068 – 11. h.
068 – 12. a.
068 – 13. k.
068 – 14. d.

069 – 1. The Specialty Description in AFR 39–1.
069 – 2. To support task and knowledge training and as a basis for career knowledge training when CDCs are not available.
069 – 3. A proficiency code in these columns indicates the extent of training needed for the task in a course and/or OJT.
069 – 4. Through OJT.

070 – 1. The STS contains the majority of tasks for which an airman is responsible.
070 – 2. By drawing a circle around the proficiency code in columns 2A, 3A, or 4A.
070 – 3. By recording the date completed and the trainee and supervisor/trainer initialing it.
070 – 4. Locally assigned tasks that are not on the STS.
070 – 5. Study/technical reference, proficiency levels, and space for trainee's and supervisor's initials.

071 – 1. Circle and initial the appropriate verb.
071 – 2. The same as any task with only one verb.
071 – 3. The same as UGT.
071 – 4. The supervisor must start the airman on a program of qualification training on that task.

072 – 1. If the JPG is not needed for recording 7-skill-level training, give it to the trainee. Otherwise, keep it for recording the UGT.
072 – 2. An airman who has dual qualification or one who is in retraining.
072 – 3. The supervisor must review each revised STS to determine if new JPGs are needed.
072 – 4. Erase the circle from the proficiency code.
072 – 5. Those applicable to the trainee's duty position.

073 – 1. For training documentation.
073 – 2. A comprehensive record of AFSC oriented training.
073 – 3. You should have an "X" by each of the following: b, d, e, f, and h.

074 – 1. At the lowest level of supervision having storage facilities.
074 – 2. To continue a filled section of AF Form 623.
074 – 3. If the airman is being separated or retired; also, upon an airman's promotion to E–7, provided it is not needed as an active training record.
074 – 4. In Section II when the trainee goes into UGT.
074 – 5. Record the date administered in column C, Section IV, AF Form 623.
074 – 6. 20 December 1978.
074 – 7. Estimated training completion date, date for supervisory evaluation, date for commander's evaluation, and the maximum training date.
074 – 8. a. I.
b. IV.
c. V.
d. V.
074 – 9. Place correction tape over the old entry. Enter the new information.

075 – 1. The immediate supervisor and the unit OJT manager.
075 – 2. To monitor the CDC progress of a trainee.
075 – 3. Once the CDC is successfully completed.
075 – 4. Upon issuance of the first volume for study.
075 – 5. The unit OJT manager.

076 – 1. Special task qualifications of a critical nature, selected tasks requiring training or evaluation, and tasks in which the supervisor relies on someone else to validate the individual's qualifications.
076 – 2. It saves the time it would take to screen entries on the JPG and AF Form 623a.
076 – 3. That the trainee must be administered both a written and practical evaluation for certification on that task.
076 – 4. The trainee must initial to indicate awareness and agreements with the applicable entries.
076 – 5. The trainee's grade and AFSC.
076 – 6. That the entry is noncurrent.

077 – 1. a. III.
b. V.
c. I.
d. IV
e. II.
077 – 2. To prepare airmen for noncommissioned officer status, and for positions of greater responsibility.

078 – 1. To motivate your trainees.
078 – 2. A goal.
078 – 3. The trainer's desire to teach.
078 – 4. By responding to the needs of the individual.
078 – 5. a. Success.
b. Self-esteem.
c. Security.
d. Enthusiasm.
e. Recognition.

CHAPTER 4

079 – 1. That most accidents can be prevented before they happen.
079 – 2. To reduce accidents throughout the Air Force.
079 – 3. If unsafe conditions are not reported it could result in inefficient and costly operations.
079 – 4. To insure that corrective action is taken.

080 – 1. Safety orientations.
080 – 2. The supervisor.
080 – 3. a. X.
b. X.
c. X.
d. A safety briefing should be given on all phases of the worker's duties at least once a week.
e. X.
f. All jobs should be explained so the workers under-stand the proper procedures for doing the work.
g. X.

081 – 1. When your body is wet.
081 – 2. Current, 100 milliamperes (0.1 ampere).
081 – 3. Regard all circuits as being live until opened, tested, and grounded.
081 – 4. "X" items a, d, f, j.
081 – 5. Rubber gloves, rubber blankets, and rubber mats.
081 – 6. The circuit may become accidentally shorted to another circuit.

082 – 1. (1) b.
(2) c.
(3) a.
(4) d.
082 – 2. The office supervisor who issues an AF Form 269.
082 – 3. Not until the clearance, with the numbers corresponding to the numbers on all red and yellow tags on the blocked device, has been released.
082 – 4. The base civil engineer.
082 – 5. None; you are not required to work under conditions that you feel are unsafe.
082 – 6. Blocking is placing a switch in the OPEN or CLOSED position and providing a means to which the switch can't be accidentally changed.
082 – 7. To make sure unauthorized persons do not change the position of the switches.
082 – 8. The actual time each switching operation is performed.
082 – 9. Part A.

083 – 1. a. X. Use a screwdriver to drive and remove screws only.
b. ____.
c. X. Store cutting tools with protective sheaths or store separate from other tools.
d. ____.
e. X. Use a hammer to hammer a rusted pipe union.
f. ____.
g. X. Keep the blades of screwdrivers ground flat and never use them as chisels.

084 – 1.
a. U. Use three-wire extension cords with three-wire equipment cords and plug them into a grounded receptacle.
b. U. Do NOT jerk the plug from a receptacle. Jerking the cord can break the cord wires or cause the connection in the plug to become loose and may cause a short circuit.
c. S.
d. U. Remove dust by ventilation before operating the motor or replace the motor with an explosion proof type.
e. S.
f. U. Tools operated on 110 volts need one hot wire, one neutral (system ground) wire, and one equipment ground wire in their cords.
g. S.
h. S.
i. S.
j. S.

085 – 1. a. S.
b. U. All electrically operated machines will be grounded.
c. U. Use a brush to remove metal cuttings from machines.
d. S.
e. U. Do not perform maintenance on moving machinery.
f. S.
g. S.

086 – 1. a. S.
b. U - Get an assistant or a forklift.
c. U - You may lift the toolbox by yourself but bend your knees and keep your back straight.
d. U - Get an assistant or use a hoist.
086 – 2. c, d, b, a, e.

087 – 1. (1) (1) c.
(2) b.
(3) a.
(4) b.

088 – 1. a. Yes.
b. Yes.
c. No. Extend an extension ladder after the ladder is against the structure.
d. Yes.
e. Yes.
088 – 2. Grasp the ladder by the rungs as you walk toward the bottom.

089 – 1. (1) e.
(2) d.
(3) g.
(4) f.
(5) b.
(6) a.
(7) c.

090 – 1. a. S.
b. U. The eyes must be immediately flushed and given medical aid in all cases.
c. U. Breathing the vapors may result in respiratory injury so ventilation is necessary.
d. S.
e. S.

091 – 1. (1) d.
(2) c.
(3) a.
(4) b.
091 – 2. Water, soda acid, and foam.
091 – 3. Foam $CO_2$, and dry chemicals.
091 – 4. Dry chemical.

092 – 1. (1) Mouth-to-mouth.
(2) Mouth-to-nose.
(3) Back-pressure-armlift.
(4) Back-pressure-hiplift.
092 – 2. No, because it may flex the neck, causing the air passages to be blocked.
092 – 3. Provides rapid reoxygenation.
092 – 4. Air is being blown in the stomach instead of the lungs.
092 – 5. Until natural breathing is restored or until a physician declares the patient dead.
092 – 6. The victim may have a facial injury.
092 – 7. Back-pressure-armlift or back-pressure-hiplift.
092 – 8. Back-pressure-hiplift.

093 – 1. (1) Evaluate the situation.
(2) Position the victim.
(3) Clear the victim's throat and mouth of any foreign matter.
(4) Begin mouth-to-mouth resuscitation simultaneously with heart massage.
(5) Continue steps.
093 – 2. In the neck.
093 – 3. 15 to 2.
093 – 4. Until you get medical aid or until rigor mortus sets in.
093 – 5. Sixty times per minute.
093 – 6. Fractured ribs, injury to spleen, liver, or other organs.
093 – 7. To prevent pneumonia.

094 – 1. (1) c.

(2) a.
(3) b.

094 – 2. To help slow down the flow of blood.

094 – 3. (1) Groin.
(2) Inner side of the upper arm.

094 – 4. Applying a tourniquet.

094 – 5. A physician.

095 – 1. It may cause bleeding to resume.

095 – 2. If air is being sucked or blown out of the chest cavity, the air could squeeze and collapse the lung.

095 – 3. It could cause infection and severe shock.

095 – 4. Because of the many blood vessels in the neck area.

095 – 5. Exert pressure on the cut by applying a sterile dressing to the wound. Next bind the dressing to protect the wound. Have the person lie down. Treat for shock.

096 – 1. a. X.
b. Wet the victim down with a wet cloth but don't cool him too fast.
c. The body temperature will be normal.
d. X.
e. The victim should get a couple of days complete rest and stay away from excessive heat.
f. X.
g. X.
h. X.
i. The pupils will be dilated.

097 – 1. Shock is a condition of great weakness of the body.

097 – 2. By doing this you lessen the chances of the victim falling into a state of severe shock.

097 – 3. This will help to prevent choking, should the victim vomit.

097 – 4. To do so may cause the pressure to drop.

097 – 5. At the same time you start the first aid.

097 – 6. Any two of the following would be correct: loss of blood, crushed bones, bone fractures, burns, and bullet wounds.

097 – 7. Yes.

1985-544-008/20064 AUGAFS,AL(852385)

STOP- 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

**EXTENSION COURSE INSTITUTE**
**VOLUME REVIEW EXERCISE**

**54250 01 22**

**GENERAL SUBJECTS**

**Carefully read the following:**

***DO's:***

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

***DON'Ts:***

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

*NOTE:* **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

## MULTIPLE CHOICE

*Note to Student:* Consider all choices carefully and select the *best* answer to each question.

1. (001) The organization on base that has the primary mission to acquire, construct, maintain and operate real property facilities is

   a. supply.
   b. comptroller.
   c. civil engineering.
   d. resource management.

2. (003) What unit under the BCE should handle the counseling of an airman for an off-base incident?

   a. Environmental Planning.
   b. Administration.
   c. Requirements.
   d. Operations.

3. (004) Which Air Force CE team has a mission to perform direct combat support with a mobile rapid response capability?

   a. Prime BEEF.
   b. RED HORSE.
   c. CEMERT.
   d. CYSCO.

4. (005) The group most likely used to repair extensive damage to a base is

   a. a RED HORSE squadron.
   b. civilian contractors.
   c. Base Civil Engineers.
   d. A Prime BEEF CF-1 team.

5. (006) What is the only rank that can hold the position of Chief Enlisted Manager (CEM)?

   a. Master Sergeant.
   b. Chief Master Sergeant.
   c. Senior Master Sergeant.
   d. Sergeant-Major of the Air Force.

6. (007) The main difference between the specialist and the technician of your career field is

   a. age.
   b. experience.
   c. skill levels.
   d. added supervisory responsibilities.

7. (017) An example of a standard publication that is nondirective is a

   a. manual.
   b. supplement.
   c. regulation.
   d. staff digest.

8. (018) A technical order issued to correct unsafe conditions that could cause a severe or fatal injury is the

   a. safety manual.
   b. abbreviated technical order.
   c. time compliance technical order.
   d. methods and procedures technical order.

9. (019) Commercial technical publications used by the Air Force

   a. are maintained in the base reference library.
   b. are never included in the TO system.
   c. are always included in the TO system.
   d. may or may not be included in the TO system.

10. (019) When a base procures locally manufactured fire alarm systems to meet an unusual situation, the vendor-supplied manuals covering the operation, service, and maintaining of these systems

a. must be indexed but need not be printed.
b. must be incorporated into the TO system.
c. need not be made a part of the TO system.
d. must be identified but need not be indexed.

11. (020) What standard publications are numbered sequentially, starting with number one each calendar year?

a. Bulletins and posters.
b. Manuals and pamphlets.
c. Regulations and manuals.
d. Staff digests and bulletins.

12. (021) The document used to index publications for an organization is

a. AFR 0-2.
b. AFR 39-1.
c. AFP 00-1.
d. AFP 85-1.

13. (022) Which technical order explains the procedures for reporting improvements in TOs?

a. TO 00-7-1.
b. TO 00-5-1.
c. TO 00-2-1.
d. TO 00-1-01.

14. (023) The *most critical* type of an AFTO 22 report is

a. an urgent report.
b. a routine report.
c. a time compliance report.
d. an emergency reports/critical hazard report.

15. (024) Without going to the index how could you determine if a binder of publications was missing from the file?

a. Check the last binder.
b. Check the binder colors.
c. Check the binder letters.
d. Check the binder numbers.

16. (025) To find a chapter or section heading in a publication, look in

a. AFR 0-2.
b. the publication index.
c. the alphabetical index.
d. the table of contents of the publication.

17. (026a) The original rationale for developing Engineered Performance Standard (EPS) was to

a. make accurate estimates of tools and materials for new construction.
b. make accurate estimates of tools and materials for maintenance of real property.
c. realize the fullest and most efficient use of manpower and money for maintenance of real property.
d. realize the fullest and most efficient use of manpower and money for new construction.

18. (026a) What is the basis for information presented in the Craft Handbooks used in Engineered Performance Standards?

a. Task - time - standard.
b. Work plan sequence.
c. Work sampling.
d. time study.

19. (026) One purpose of the facility survey is to provide

a. a time for work to be done.
b. the money and time to do the work.
c. budgetary guidance for the base commander.
d. inputs to the civil engineering work plan.

20. (026) The Inservice Work Plan (IWP) is compiled by which of the following?

a. The BCE.
b. Facility Survey.
c. Production Control.
d. The shop supervisors.

21. (027) If you know the scope and level of the job without visiting the job site, you would

a. send the schedule to BCE.
b. not need to schedule the work.
c. send the schedule to your supervisor.
d. visit the job site to confirm what you know.

22. (028) Man-hour accounting provides CE management and base accounting and finance with

a. direct labor costs.
b. total costs of a job.
c. direct labor costs against work order numbers.
d. material and labor costs against work order numbers.

23. (029) The code used to identify the total number of direct labor hours against each work order number is

a. TAM.
b. LUC.
c. LOP.
d. ATA.

24. (029) When a change of cost center is involved,

a. no report is required.
b. the subcost center number is entered.
c. loaned and borrowed labor are reported.
d. individual names by work order number are reported.

25. (030) Work control and planning are examples of what type cost centers?

a. Exception time accounting.
b. Indirect time accounting.
c. Actual time accounting.
d. Direct time accounting.

26. (031) A team of workers of different skills that work from a trailer are used to accomplish work from what type of work order?

a. SMART.
b. Urgent.
c. Routine.
d. Emergency.

27. (031) A work order authorized on AF Form 1219 is

a. either a SMART or an MFH renovation work order.
b. either a service call or an MC work order.
c. performed from a DIN truck.
d. an MC work order.

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28. (031) The decision to use a work order is based on need for the following *except*

a. detailed planning.
b. collecting reembursement.
c. size and complexity of the job.
d. capitalization of real property records.

29. (032) In which of the following cases could DD Form 362, Statement of Charges for Government Property Lost, Damaged or Destroyed, be used?

a. Enlisted or civilian employee for an amount of more than $500.
b. Enlisted or civilian employee for an amount less than $500.
c. Officer for an amount of less than $250.
d. Officer for an amount of more than $250.

30. (032) If a Report of Survey, DD Form 200, is initiated, how many officers are directly involved in preparing the report?

a. 5.
b. 4.
c. 3.
d. 2.

31. (033) The TA-001 is the

a. Numerical Index.
b. stocklist of items.
c. TA for power linemen.
d. Master Equipment Management Index.

32. (036) Bench stocks are normally limited to

a. sixty day stock levels.
b. common nonrecoverable hardware items.
c. small hand tools and expendable items.
d. daily requirement items of hardware and materials.

33. (036) If the 14 digit supply transaction code, the last four numbers refer to which of the following?

a. Organizational code.
b. Item serial number.
c. Bench stock code.
d. Shop code.

34. (037) When should a bench stock bin be flagged?

a. AT 75 percent level.
b. At 50 percent level.
c. At 25 percent level.
d. At 10 percent level or 5-day supply.

35. (038) What would be the color of the condition tag that you would attach to an electric drill that has a broken plug?

a. Red.
b. White.
c. Green.
d. Yellow.

36. (038) If you are set to get an electric drill and three drills are available, one tagged red, one tagged green, and one tagged yellow, what action do you take?

a. Do not select any of the drills as all are inoperable.
b. Select the drill with the yellow tag.
c. Select the drill with the green tag.
d. Select the drill with the red tag.

37. (039) The document used for expendable item turn-ins is

a. AF Form 1801.
b. AF Form 1445.
c. AF Form 6016.
d. DD Form 1574.

38. (040) What form should be used for a temporary issue document?

a. AF Form 1492.
b. AF Form 1297.
c. AF Form 601b.
d. AF Form 1801.

39. (041) The two documents needed to consult in case of a materiel deficiency are

a. AFR 52-3 and AFM 66-10.
b. AFM 127-101 and AFR 52-6.
c. TO 00-35D-54 and AFR 66-30.
d. AF Form 1382 and DD letter 105-1.

40. (042) The primary reason for full and frank discussions of the unit mission with your subordinates is

a. the goals set by your boss.
b. the accomplishment of the mission.
c. your esteem with your subordinates.
d. the feelings of your subordinates.

41. (043) Before you can supervise others, you must be able

a. to understand human behavior.
b. to state the procedures for doing the job.
c. to basically understand the job.
d. to correctly do the job yourself.

42. (044) You supervise an electrical crew and have been given a job that requires the crew to work all weekend, but some members of the crew have plans to attend an out-of-town football game on Saturday. What action should you take?

a. Try to talk your boss out of doing the job at this time.
b. Let the ones of the crew off that have already made other plans.
c. Tell the crew that anyone not present cannot be expected to do the job.
d. Explain to the crew all the facts and reasons why the job must be done at this time when you explain the job.

43. (045) What is the *most important* part of new worker orientation?

a. To let the new worker known who is boss.
b. To introduce him or her to the job and to the people.
c. To provide detailed information about every aspect of his or her job.
d. To get it over with quickly so the new workers can start their new job.

44. (045) During the walk-around part of an orientation, the new assignee should be given a

a. general overview of the shop and of his or her job.
b. detailed account of the shop and of his or her duties.
c. casual, off-hand introduction to his or her co-workers.
d. detailed list of tools and equipment that he or she will need.

45. (046) In setting work priorities,

a. all jobs have the same importance.
b. all workers should be assigned to the same task difficulty jobs.
c. job classification and work priorities are the same thing.
d. only jobs essential to the organization's mission should be done.

46. (046) Work assignment should be made

a. according to the skills required of the job to be done.
b. by allowing each person to work at his best pace.
c. according to the amount of work to be done.
d. on a first come-first served basis.

47. (047) Using common sense to get the job done efficiently is called

management.
supervision.
c. organization.
d. coordination.

48. (048) Why should a worker repeat instructions that they receive from the supervisor?

a. To assure the supervisor that instructions are correct.
b. To assure understandings of the instructions.
c. To assure speed and efficiency.
d. to assure compliance.

49. (049) If you know of impending changes you should

a. wait until they happen then tell your workers.
b. keep them to yourself as they might not happen.
c. tell your workers if the change will affect them.
d. tell your worker whether they are affected or not.

50. (050) The first factor to be considered in solving a problem is to

a. send the individual to the proper referral agency.
b. discuss the actions with the individual.
c. define the problem.
d. get the facts.

51. (051) The basic requirement for true counseling is

a. empathy.
b. sympathy.
c. self esteem.
d. a protective attitude.

52 (052) An atmosphere of mutual trust and understanding is called

c. evaluation.
d. prob[illegible]m solvi[illegible]

[illegible] (05[illegible]) [illegible]mance standards should cover which of the following?

a. Quality of work only.
b. Quantity of work only.
c. Quantity and quality of work.
d. Quantity, quality, and time of work.

54. (054) Personnel evaluations should be based on which of the following?

a. the supervisor's appraisal only.
b. a mutual respect between supervisor and worker.
c. a mutual agreement on the effectiveness of the worker.
d. a mutual understanding of performance standards.

55. (055) The form used to prepare an Airman Proficiency Report for SSgt Jones is

a. AF Form 912.
b. AF Form 911.
c. AF Form 910.
d. AF Form 909.

56. (055) If you advertantly mismark a block in section III of an APR you must

a. reaccomplish the APR.
b. scratch through the error and remark the entry.
c. circle the block, initial, and change the entry.
d. white out this block, initial, and change the entry.

57. (056) What Air Force Regulation establishes policy and procedures for the performance appraisals of civilian personnel?

a. AFR 50-10.
b. AFR 50-351.
c. AFR 50-561.
d. AFR 40-452.

58. (056) What is the basis of the duties and responsibilities listed on the AF Form 1282, Job Performance Appraisal, for civilian employees?

a. Critical job elements.
b. Noncritical job elements.
c. The unit mission.
d. The projected shop load.

59. (077) Professional Military Education (PME) is designed to

a. teach you about your AFSC.
b. help you progress in grade.
c. teach you about the Air Force.
d. prepare you for noncommissioned officer status.

60. (078) Two points at which you should help trainees identify needs and goals are

a. formal and informal counseling.
b. weekly and monthly safety meetings.
c. formal counseling and shop meetings.
d. orientation and training evaluations.

61. (079) The percentage of accidents that are caused by physical [illegible]azards is

a. 2 [illegible]nt.
b [illegible]ent.
[illegible]cen[illegible]
d. [illegible]ent.

62. (0[illegible]) should a worker repeat orders that concern jobs that are particularly hazardous?

a. to provide a record in case there is a slip-up.
b. to help the worker understand the tasks required.
c. To let the supervisor know that the worker understands the job
d. So that the worker and the supervisor can agree on what is to be done.

63. (081) The cause of electric shock is

a. Power in the circuit.
b. Resistance of your body.
c. Current through your body.
d. voltage through your body.

64. (082) Who has the responsibility for safe clearance procedures?

a. The BCE.
b. The worker.
c. The foreman.
d. The supervisor.

65. (082) AF Form 26 ... ...

a. to record the names of the crew that are performing the task.
b. only for protection of men working under safe clearance.
c. for abnormal operating conditions of lines or equipment.
d. to control and record all blocking and tagging.

66. (082) Who is responsible for notifying users of a power outage?

a. The issuing office supervisor.
b. The Ground Safety Officer.
c. The Base civil Engineer.
d. The Shop Supervisor.

67. (083) Which of the following actions is *most likely* to cause injury to the palm of your hand?

a. Using a sharp tool.
b. Using a rasp without a handle.
c. Using a hammer with a loose handle.
d. Using a cold chisel with a mushroomed head.

68. (084) What type electric cord must be installed on uninsulated power tools and plugged into what type receptacle?

a. Two-wire cord, grounded receptacle.
b. Three-wire cord, grounded receptacle.
c. Two-wire cord, ungrounded receptacle.
d. Three-wire cord, ungrounded receptacle.

69. (085) What should be used to remove metal chips from a drill press table?

a. Hands.
b. Broom.
c. Brush.
d. Magnet.

70. (086) [illegible] joints of [illegible] are

a. [illegible] and back.
b. hips and waist.
c. knees and hips.
d. ankles, knees, and hips.

71. (087) How many pounds are *most* single ladders designed to support?

a. 1250 lbs.
b. 1000 lbs.
c. 750 lbs.
d. 500 lbs.

72. (088) How far away from the structure should the base of a straight ladder be?

a. 36 inches.
b. 1/4 the length of the ladder.
c. 1/3 the length of the ladder.
d. It doesn't need to be pulled out.

73. (088) The locking device is locked on a stepladder by

   a. engaging the braces.
   b. putting weight on the back legs.
   c. putting weight on the front legs.
   d. spreading the back legs away from the front legs.

74. (089) What ladders are *never* used when working on live circuits?

   a. Ladders equipped with safety shoes.
   b. Fiberglass.
   c. Wooden.
   d. Metal.

75. (089a) What is the goal of the Hazardous Materials/Waste program?

   a. To prevent contamination.
   b. To prevent electrocution.
   c. to prevent jet-engine damage.
   d. To prevent accidental explosion of munitions.

76. (089a) What is the required action to take for spilled liquid chemicals?

   a. Flush chemicals down a drain.
   b. Dilute chemicals and pour them into a sewer.
   c. Cover chemicals with a plastic tarpaulin.
   d. Cover chemicals with an absorbent material.

77. (091) In a Class "A" fire, water

   a. has no effect on combustible metals.
   b. puts out the fire by cooling and quenching.
   c. spreads the fire because oil floats on water.
   d. provides a path for electricity to follow you.

78. (091) Combustible metal fires are

   a. Class A.
   b. Class B.
   c. Class C.
   d. Class D.

79. (092) How much of the oxygen content of each breath do your lungs extract?

   a. 10 percent.
   b. 25 percent.
   c. 50 percent.
   d. 100 percent.

80. (092) The purpose for keeping a person lying down after receiving artificial respiration is to

   a. reduce the probability of a stroke.
   b. prevent unconsciousness.
   c. avoid heart strain.
   d. prevent shock.

81. (093) The purpose of closed chest cardiac massage is to provide

   a. artificial blood flow.
   b. stimulation to the lungs.
   c. oxygen to the victim's lungs.
   d. supplemental aid to the heart.

82. (094) A victim has an injury from which bright red blood is being lost. This injury is

a. serious, as an artery has been punctured.
b. serious as a major vein has been severed.
c. not serious as a vein has been punctured.
d. not serious as this is capillary bleeding.

83. (095) What is the major danger of a sucking chest wound?

a. Bacteria.
b. Broken bones.
c. Loss of blood.
d. A collapsed lung.

84. (095) On a cut or wound, when bleeding has been controlled, you should

a. cover the wound with a dressing held in place by a bandage.
b. leave the wound open so air can get to the wound.
c. apply a tourniquet at the next joint.
d. wash the wound with hot soapy water.

85. (096) Basically, heat exhaustion is

a. caused by a loss of minerals.
b. caused by loss of body liquids.
c. caused by the inability to sweat.
d. a malfunction of the nervous system.

86. (097) One treatment for shock is to

a. keep the victim cool.
b. keep the victim warm.
c. keep the victim walking around.
d. give the victim strong stimulants.

**END OF EXERCISE**

MAIL TO: ECI, GUNTER AFS AL 36118-5643

# STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 10 USC 8012. PRINCIPAL PURPOSE: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package, and used by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's inquiry. Failure to provide all information would result in slower action or inability to provide assistance to the student.

I. CORRECTED OR LATEST ENROLLMENT DATA

| 1. THIS REQUEST CONCERNS COURSE (1-6) | 2. TODAY'S DATE | 3. ENROLLMENT DATE | 4. AUTOVON NUMBER |
|---|---|---|---|
| | | | |

| 5. SOCIAL SECURITY NUMBER (7-15) | 6. GRADE/RANK | 7. NAME (First initial, second initial, last name) |
|---|---|---|
| – – | | (17) – (18) – (19-32) |

| 8. ADDRESS | |
|---|---|
| OJT ENROLLEES--Address of unit training office with zip code. ALL OTHERS--Current mailing address with zip code. | (33-53) <br> (54-75) |
| 9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE | 10. TEST CONTROL OFFICE ZIP CODE/SHRED (33-39) |

II. REQUEST FOR MATERIALS, RECORDS, OR SERVICE

FOR ECI USE ONLY

| X | *Place an 'X' through number in box to left of service requested.* | | |
|---|---|---|---|
| 1 | Request address change as indicated in Section I, Block 8. | | |
| 2 | Request Test Control Office change as indicated in Section I, Block 10. | | |
| 3 | Request name change/correction. *(Provide Old or Incorrect data here)* | | |
| 4 | Request Grade/Rank change/correction. | | |
| 5 | Correct SSAN. *(List incorrect SSAN here.)* *(Correct SSAN should be shown in Section I.)* | | |
| 6 | Extend course completion date. *(Justify in "Remarks")* | | |
| 7 | Request enrollment cancellation. *(Justify in "Remarks")* | 16 G | 33 |
| 8 | Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 10 <br> Originals were: [ ] Not received [ ] Lost [ ] Misused | K | VOL 33-35 GR 36-38 |
| 9 | Send course materials. *(Specify in "Remarks")* <br> [ ] Not received [ ] Lost [ ] Damaged | M | 33-34 35-40 |
| 10 | Course exam not yet received. Final VRE submitted for grading on __________(date). | N | 33-35 |
| 11 | Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 10 not yet received. <br> Answer sheet(s) submitted __________(date). | P | VOL 33-35 |
| 12 | Results for CE not yet received. Answer sheet submitted to ECI on __________(date). | P | TC 36-37 38 |
| 13 | Previous inquiry ([ ] ECI Fm 17, [ ] ltr, [ ] msg) sent to ECI on __________(date). | P | DOE 39-45 |
| 14 | Give instructional assistance as requested on reverse. | Q | 33-34 ØØ 38 1 |
| 15 | Other *(Explain fully in "Remarks")* | Q | MC 39-42 |

REMARKS *(Continue on reverse)*

| | |
|---|---|
| *OJT STUDENTS must have their OJT Administrator certify this record.* <br> *ALL OTHER STUDENTS may certify their own requests.* | *I certify that the information on this form is accurate and that this request cannot be answered at this station.* <br> SIGNATURE |

ECI FORM 17 DEC 84 PREVIOUS EDITION WILL BE USED.

## REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of subject matter should be forwarded directly to preparing agency. For an immediate response to these questions, call or write the course author directly, using the AUTOVON number or address in the preface of each volume. All other inquiries concerning the course should be forwarded to ECI.

| VRE ITEM QUESTIONED: | MY QUESTION IS: |
|---|---|
| COURSE NO ____ | |
| VOLUME NO ____ | |
| VRE FORM NO. ____ | |
| VRE ITEM NO ____ | |
| ANSWER YOU CHOSE ____ (Letter) | |
| HAS VRE ANSWER SHEET BEEN SUBMITTED FOR GRADING? ☐ YES ☐ NO | |
| REFERENCE | |
| *(Textual reference for the answer I chose can be found as shown below.)* | |
| IN VOLUME NO ____ | |
| ON PAGE NO ____ | |
| IN ☐ LEFT ☐ RIGHT COLUMN | |
| LINES ____ THROUGH ____ | |

REMARKS

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. Course workbooks have a Form 17 printed on the last page.

ECI FORM 17, DEC 84 *(Reverse)*

AU GAFS, AL (881775) 1300

54250 02 8210

CDC 54250

# ELECTRICIAN

**(AFSC 54250)**

**Volume 2**

*Basic Electricity and Installing*

*Electrical Systems*

# Extension Course Institute
# Air University

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# Preface

THIS SECOND volume of CDC 54250, ELECTRICIAN, is concerned primarily with the installation and maintenance of interior electrical systems. However, information is also included on tools and supplies. This volume covers electrician's hand and power tools; electrical and electronic principles; electrical materials and devices used for interior electrical systems installation of service and distribution panels; circuit installation with nonemtallic cable, circuit installation with conduit, planning and laying out work; meters and test equipment; and interior electrical system maintenance, troubleshooting, and repair.

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# Contents

**NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a three-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.**

# Basic Electricity

MOST OF US know something about electricity because electrical devices and appliances have become a part of our everyday life. We flip a switch and a lamp gives us light. We turn a radio knob and hear music. We turn on an electric fan or a washing machine and parts begin to move. We know, then, that we can put electrical energy to work.

All of the things just mentioned are common, everyday occurrences. In fact, they are so common that we seldom stop to ask how they are possible. The answer is quite simple and very interesting.

In this chapter we will discuss the principles of electricity and electrical terms, such as voltage, current, resistance, magnetism, and electromagnetism. It will also include direct and alternating current circuits, power sources, transformer theory, and solid-state devices.

## 1-1. Electrical Principles

All activity that takes place in any type of electrical circuit depends on the behavior of tiny electrical charges called electrons. To understand the behavior of electrons, you must first understand the nature of matter. Hence, your first step in the study of electricity involves learning how electrons fit into the world of physical things that surround us.

**200. Describe matter, differentiate between compounds and mixtures, and specify what makes electrical current.**

**Matter.** Have you ever considered that everything around you, even the air you breathe, occupies space and has weight? Anything that meets this description is called matter. With this definition, you would be hard pressed, in fact it is impossible, to name a physical substance or object that is not matter. Coal, water, wood, gas—all are examples of matter.

Just what makes up matter? Matter is made up of very small units called molecules. The molecules are made up of atoms. The atoms, in turn, are made up of minute particles called protons, neutrons, and electrons.

**Elements.** Not only does matter consist of the minute particles mentioned in the preceding paragraph, but it can also be stated that all matter is composed of elements. Elements are the so-called building blocks of nature. They cannot be divided or reduced to a simpler substance by chemical means. Examples of elements are pure iron, gold, silver, copper, hydrogen, and oxygen. There are some 100 plus natural elements known to humankind. All of the familiar substances in our universe are composed either of these elements or of combinations of them. There are about a dozen other elements that have been prepared synthetically (manmade) in laboratories.

Elements may be combined in two different ways, either in compounds or mixtures. A compound is a combination of elements that can be separated only by chemical means. An example of a familiar compound is pure water (which is composed of the elements hydrogen and oxygen). A mixture, on the other hand, is a combination of elements or compounds that can be separated by physical means. Examples of mixtures are brass (a mixture of copper and zinc) and air (a mixture of nitrogen, oxygen, carbon dioxide, and several other gaseous substances).

**Molecules.** We find that a drop of water can be divided into many small parts. In fact, it can be divided until the parts are no longer visible, yet each part still retains the characteristics of the original drop. The smallest part of a substance that has all the characteristics of that substance is called a molecule. A single drop of water is made up of many millions of molecules, as are all other substances.

A molecule of water is expressed chemically as $H_2O$, meaning that each molecule is composed of two distinct elements. $H_2O$ stands for the combination of two parts of the element hydrogen ($H_2O$) and one part of the element oxygen (O). The water molecule has a very simple structure, consisting of only two common elements. Molecules of other substances may be more complex, sometimes consisting of several elements. Just what makes up molecules? Perhaps, more specifically, we should ask what elements make up molecules?

**Atoms.** The individual elements that combine to form molecules are made up of atoms. For a long time it was though that the atom was the smallest subdivision of matter. However, in recent years the electron theory has been advanced; it helps to explain many electrical and chemical phenomena. According to the electron theory, atoms are composed of minute units called protons, neutrons, and electrons. Furthermore, all the atoms that make up a particular element are identical in their structure. The reason for the different types of elements then—why iron differs from oxygen, for example—is that the protons, neutrons, and electrons differ in number and are arranged differently within the atoms of each element.

Each proton and each electron carries an electrical charge—protons carry a positive charge, whereas electrons carry a negative charge. The neutrons carry no charge. The electron theory explains that all atoms are similarly constructed of a central nucleus and orbiting electrons. The protons and neutrons are contained in a closely packed nucleus in the center of the atom. The electrons spin around the nucleus in much the same manner that the planets move around the sun.

You may recall from your high school science that our solar system has nine planets that revolve around the sun. In the same manner, one atom may have nine electrons spinning around its nucleus; other atoms may have more or fewer electrons.

Figure 1-1 shows you the atomic structure of four common atoms. Notice that tne structure of each is similar and can be compared with our planet earth and its relationship with the sun. The hydrogen atom, as shown in the figure, is the simplest of all atoms. It contains one electron revolving around one proton, which acts as a nucleus. Because the negative charge of the electron is equal to the positive charge of the protn, the atom is electrically balanced or neutral. For simplification, only the charged units (proton and electron) of the atom are shown in the illustration. However, as we previously discussed, the nucleus of all atoms contains neutrons as well as protons. A proton is said to weigh many times (about 1840 times) more than an electron.

Take a look at the helium atom in figure 1-1. You notice that the nucleus contains two protons. The positive charges of these two protons are balanced by the negative charges of the two revolving electrons, and the electrical charge of the entire atom is neutral. Atoms of other elements are more complex than the hydrogen and helium atoms. For example, look at the lithium atom shown in figure 1-1. Notice that there are three electrons revolving around the nucleus in two different paths or orbits. An even more complex atom, the carbon atom, is also shown in the figure. It has six electrons revolving around the nucleus in two different paths.

The four common atoms shown in figure 1-1 illustrate the electron theory that the only difference in atoms of the various elements is in the number and arrangement of the protons, neutrons, and electrons. In some elements, the electrons in the outer paths are called free electrons because they can be dislodged from the regular path and be made to move from one atom to another. It is the movement or displacement of these free electrons that gives us electrical energy.

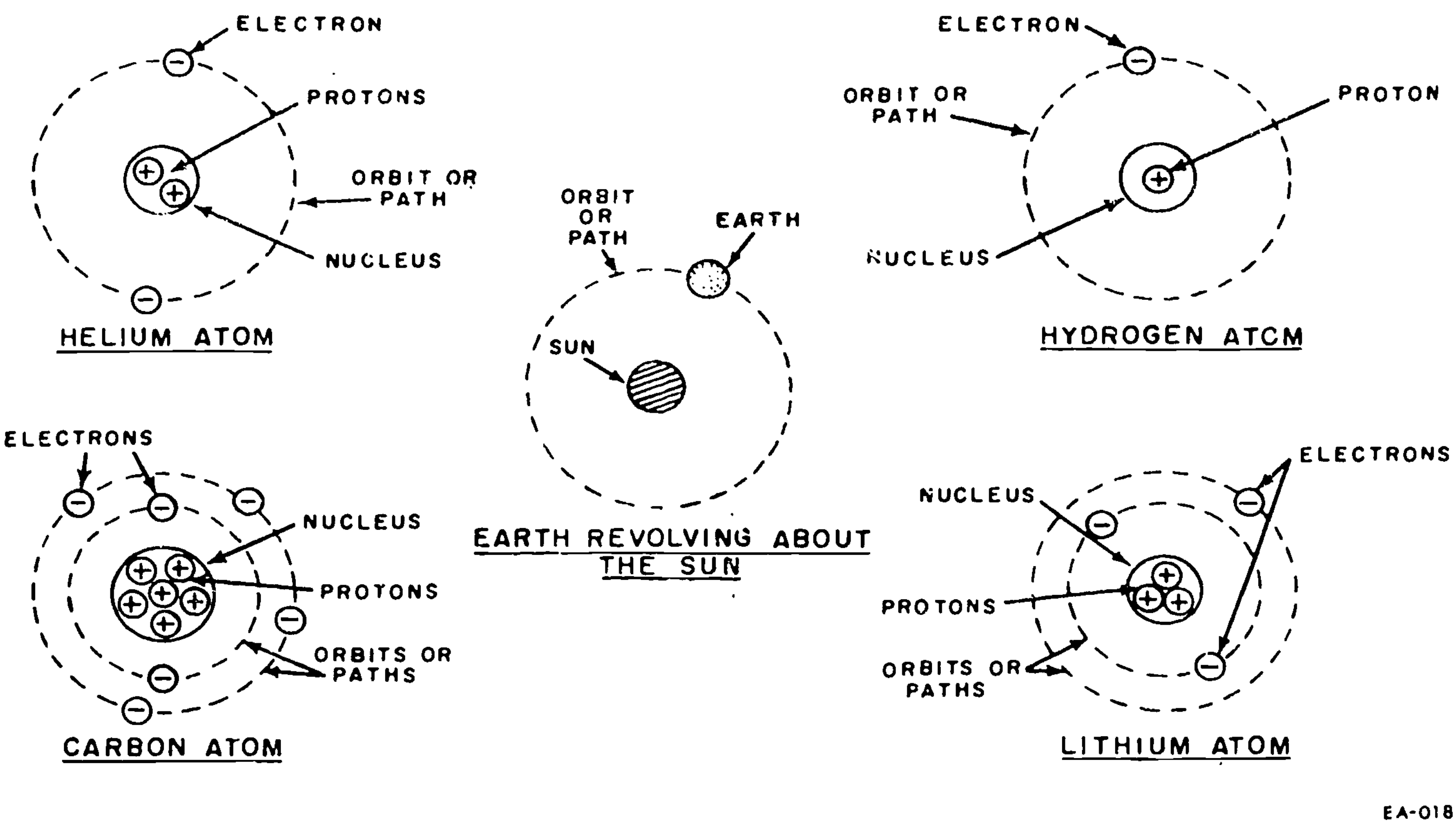


Figure 1-1. Structure of common atoms.

**Electron Flow.** Electrons moving or flowing through a conductor (wire) are called an electric current. The electric current always flows from a point of negative potential (excess of electrons) to a point of positive potential (deficiency of electrons).

Current flowing through a conductor may be compared to water flowing through a pipe. If we have a pipe full of water and pump in more water at one end, water is forced out of the other end. If a copper wire containing billions of free electrons in the outer paths of the copper atoms has electrons forced into one end of the wire, electrons are forced out of the other end. The excess of electrons at one end forces an electron away from a nearby atom and causes it to crowd an electron away from the next atom, and so on. This electron flow principle is illustrated in figure 1-2. Imagine an almost instantaneous shift of billions upon billions of free electrons throughout the entire length of the conductor, and it is not difficult to picture the electric current. Science tells us that current (electron flow) flows through a conductor at the speed of light (186,000 miles per second).

**Exercises (200):**

1. What are known as the building blocks of nature?

2. Describe matter.

3. With what is current flowing through a conductor compared?

4. Water is expressed chemically as $H_2O$. Of what elements is it composed?

5. Explain the difference between compounds and mixtures.

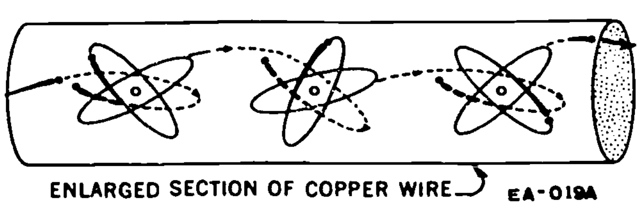


Figure 1-2. Electron movement in a conductor.

6. What is the smallest part of a substance that has all the characteristics of that substance called?

7. What are the elements called that form molecules?

8. Electrical current is composed of what?

**201. Define voltage, indicate the effects of current, and specify the unit of measurement for resistance.**

**Fundamentals of Electricity.** There are three fundamental factors that must be present before you can have an operating electrical circuit—voltage, current, and resistance. If you understand the relationships among these three units, then you have a good foundation toward understanding and increasing your knowledge of electricity. This objective is devoted to a discussion of electrical units.

*Voltage*. Just as you need a pump of some sort to keep water flowing through a pipe, an electrical pressure is also needed to make current flow through a conductor. The pump that produces this pressure may be a battery or an electric generator that can produce a potential difference in the conductor. Water pressure is measured in pounds per square inch; electrical pressure is measured in volts. One volt is the electrical pressure required to force 1 ampere of current through a resistance of 1 ohm. Electrical pressure, electromotive force (EMF), and potential difference are used interchangeably; they all mean the same thing—voltage. The basic unit of measurement for voltage is the volt.

The voltage of an ordinary dry cell battery, such as a flashlight battery, is 1.5 volts. The voltage for most domestic electrical service is about 120 volts. When voltage is applied to a circuit, a certain amount of current will flow through the circuit. If the voltage is increased, then the current flow will increase in direct proportion to the voltage.

*Current*. You have already learned that current flow is simply the movement of electrons through a conductor. Electric current and some of its effects were discovered long before the electron. The fact that current flow through a circuit was in a given direction was also known. It was this fact that gave rise to the concept of polarity.

To provide a standard method of indicating the direction of current flow, one terminal of the early chemical cell used as a source of electrical energy was marked positive (plus); the other terminal was labeled negative (minus). It was then assumed that when a circuit was connected to the cell terminals, a current would flow through the circuit from the positive terminal to the negative terminal (plus to minus). This theory (conventional current flow), however, soon gave way with the discovery of the electron. We now know

that when a circuit is connected to the terminals of a battery, current flows through the circuit from the negative terminals to the positive terminal (electron flow theory).

Current has four effects—heat, magnetism, chemical action, and physical shock. Current always produces heat when it flows through a conductor. The amount of heat produced depends on the material of the conductor and on the amount of current flowing. For example, electric irons and toasters must have heating elements that produce enough heat to be practical. The light produced by an electric lamp is caused by current flowing through a threadlike conductor inside the lamp, called a filament. However, the conductor that carries the current to the filament must not become hot enough to glow.

Magnetism is produced when current flows in a conductor. This is a very important effect, for it is the basis for millions of electrical machines, such as generators, motors, and electromagnets. Without this effect, there is no known way to generate electricity cheaply and convert it into mechanical energy to perform work.

Current produces chemical action when it flows through a liquid. Examples of this effect are the charging of a storage battery and the electroplating process. Physical shock is the unpleasant and sometimes dangerous sensation caused by coming into contact with a source of electric energy. We often speak of voltage as the cause of shock; however, the fact is that current flowing through the human body produces the physical shock. The pain and the muscular contraction are due to the effect of current on the nerve centers and on the nerves themselves.

Current is measured in terms of the number of coulombs that pass by a given point in 1 second. When a conductor is connected across a source of voltage and $6.28 \times 10^{18}$ electrons (one coulomb) pass through the conductor in a period of 1 second, then one unit of current flow has occurred. This unit of current flow is called an ampere.

*Resistance*. The definition of resistance means the opposition to the movement of free electrons through a circuit or conductor. The amount of opposition offered by a conductor depends on the material of the conductor, its length, its cross-sectional area, and its temperature.

Resistance to electric current is present in all matter, but one material may have much more resistance than another. Air, rubber, glass, and porcelain have so much resistance that they are called insulators and are used to confine electricity to its proper circuit. The rubber covering on the wires to an electric lamp prevents the wires from touching each other and causing a short circuit. The rubber also protects a person who is using the lamp from receiving an electric shock. Air acts as an insulator whenever a light switch is opened. Air fills the gap between the open contacts of the switch, and no current flows because of the high resistance. However, even air may act as a conductor if the voltage is high enough; otherwise, there could not be the discharge that appears in a lightning stroke.

Metals are good conductors of electricity, but some are better than others. Copper and silver are both good conductors of electricity because of their relatively low resistance. Aluminum is not as good but is used for long overhead spans because of its light weight. Steel is a poor conductor, although it is used in combination with aluminum for added strength. Alloys of nickel and chromium are used in heater elements to provide a specific resistance that passes enough current to heat the elements to a red glow. The alloy makes it possible to operate the elements at high temperatures without melting them. Since copper is a good conductor and is relatively inexpensive, it is widely used in electrical circuits. However, copper is seldom used in its pure form. it usually is mixed with other metals to form a copper alloy.

The resistance of a copper wire is determined by three things—the cross-sectional area of the wire, its temperature, and its length. Since a wire with a large diameter has a greater cross-sectional area than a smaller wire, it, therefore, has less resistance. A long wire has more resistance than a short wire. A cold wire has less resistance than a hot wire. The ohm is the standard unit of measurement for resistance.

**Exercises (201):**

1. What is voltage?

2. What effects does current have?

3. What is produced when current passes through a conductor?

4. Silver and copper are considered good conductors because of their low resistance. How is the resistance of a conductor determined?

5. What is the standard unit of measurement for resistance?

**202. Differentiate between types of magnets, state specified characteristics of magnets, and define lines of force.**

**Magnets.** A magnet is an object that has the property of attracting iron and steel, and, if permitted to turn freely, will rotate to a definite direction. Magnets attract other materials, such as nickel and cobalt, but not with as much force as iron and steel. Materials that can be attracted by magnets are called magnetic substances. There are two principal kinds of magnets—natural magnets and artificial magnets. Natural magnets are found in nature already magnetized, whereas artificial magnets must be made by

magnetiziing iron or steel. Artificial magnets can be either permanent or temporary.

*Natural magnets*. A black mineral ore called lodestone or magnetite, found in plentiful supplies in Asia Minor, exhibits magnetic properties. Lodestone is called a natural magnet because it exists in nature already magnetized. Historically, lodestone has played an interesting role. It was used in the Middle Ages to magnetize compass needles. Today, however, lodestone has very little value as a magnet, chiefly because of its unstable physical structure and low magnetic strength.

*Artificial magnets*. Artificial magnets are made of iron and steel. They are magnetized by induction from some external object, by stroking with some other artificial magnet, or by being placed in the field of an electromagnet (electromagnets are described later). Hard steel will hold its magnetism for a long period of time, and for this reason permanent magnets are made of hard steel and other substances that have the same characteristics. They are made in various shapes. Soft iron can be magnetized easily but loses its magnetism quite rapidly. The property of a substance that causes it to remain magnetized is called retentivity, and the magnetism that remains is called residual magnetism. Steel has high retentivity, whereas that of soft iron is low.

*Lines of force*. It is a fact that magnetic lines of force surround the earth in much the same way that lines of force surround a bar magnet. Also, the earth has two magnetic poles, one near the geographic North Pole and the other near the geographic South Pole. These are facts responsible for our most important navigational instrument—the magnetic compass. Dating back to the Middle Ages, the magnetic compass is still the most widely used navigational instrument. Basically, it is an artificial magnet mounted in such a way that it aligns itself with the earth's magnetic lines of force, with one end of the magnet always pointing toward magnetic north.

When a bar magnet is dipped into iron filings, a large number of filings will cling to the magnet near its ends, but few will attach themselves to the magnet near its center. This action indicates that the magnetism is concentrated at the two ends. These ends are called the poles of the magnet. The magnetic strengths of the two poles of any magnet are equal. A magnet, free to rotate, will always turn to a north-south direction, aligning itself with the earth's magnetic field. The pole of the magnet that always turns toward the north is called the north-seeking pole, or simply the north pole (N); the pole at the opposite end is called the south-seeking pole, or south pole (S).

Placing a sheet of glass or some other nonmagnetic substance over a magnet and sprinkling iron filings on it will provide you a means of observing the configuration of the magnetic field. If you tap the glass, the filings will aline themselves into chains or lines, producing a facsimile of the magnetic field itself. At any particular point in the space around the magnet, there is a state of stress that exerts a force on any pole brought into the vicinity of the magnet. The direction that such a force takes indicates the direction of the magnetic field at that point, and lines connecting the direction of the field at a series of points form lines called lines of force. It is along these lines of force that iron filings align themselves.

Figure 1-3 shows the theoretical lines of force about a bar magnet and a U-shaped magnet. Lines of force travel from the N-pole to the S-pole, have only one direction at a given point, and form closed loops. The path of each loop is from the N-pole to the S-pole in space, and through the magnet to the N-pole. When two magnets are brought together, the fields of stress interact, causing repulsion or attraction, depending upon the polarity of the poles.

**Exercises (202):**

1. What is the difference between the two types of magnets?

2. What is meant by the lines of force around a magnet?

3. Why does lodestone have little value as a magnet today?

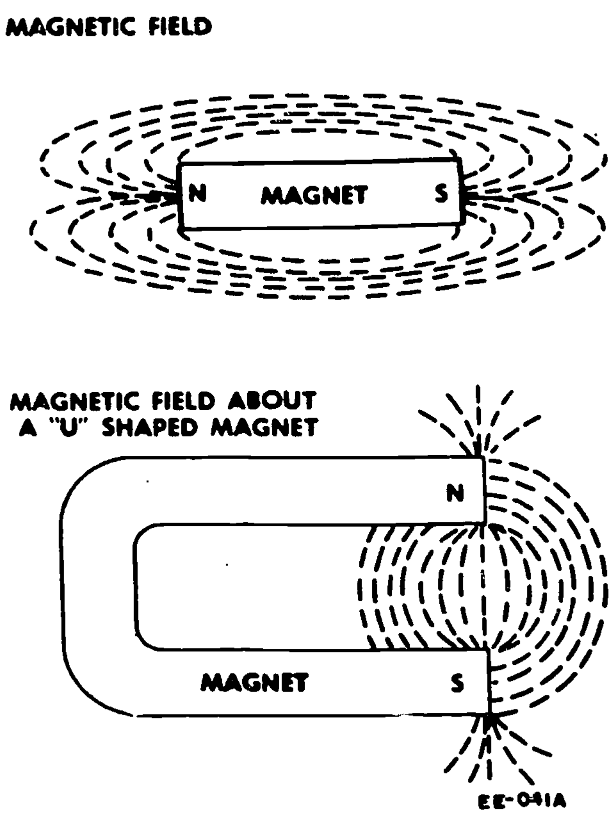


Figure 1–3. Lines of force.

4. From what material is a permanent magnet made? Explain why.

5. What direction will a magnet turn when free to rotate?

6. What happens when two magnets are brought together?

**203. Identify electromagnetism and magnetic circuit.**

**Electromagnetism.** Over a century ago, Oersted, a Danish physicist, discovered the fact that a current-carrying conductor is surrounded by a magnetic field. He also discovered that the magnetic field's strength diminishes directly as the distance from the center of the conductor increases and that lines of force form about the conductor.

*Lines of force in a conductor.* The lines of force about a current-carrying conductor travel in either a clockwise or a counterclockwise direction, depending upon the direction of electron flow. For example, at A in figure 1-4, the electrons are moving into the page. In this case, the direction of the field about the conductor is counterclockwise. At B, the electrons are moving out of the page and the direction of the field is clockwise. To determine the direction of the lines of force about any conductor, use the left-hand thumb rule, which states that if you grasp a conductor with your left hand in such a manner that your thumb points in the direction of electron flow, your fingers will indicate the direction of the lines of force, as shown in figure 1-4. If you bend a straight conductor into a single turn loop, as is shown in figure 1-5, the lines of force will concentrate within the loop. This concentration is due to the fact that all lines of force enter the loop from one side and leave it at the other. If you wind several turns of wire close together into the form of a coil, the magnetic fields about each turn will all have the same direction.

When current flows through this wire, the coil (or solenoid) is surrounded by a magnetic field like that shown in figure 1-6. One end of this coil is called the north magnetic pole, and the other end the south magnetic pole. To determine the polarity of a coil, use the left-hand rule (fig. 1-7) as follows: Grasp the coil with the left hand so that the fingers point in the direction of electron flow, and note the direction the thumb points. This direction is the north pole. Inserting a soft iron core into a solenoid greatly increases the number of magnetic lines of force. This increase in magnetic lines is not caused by an increase in the intensity of the field, but from additional lines produced by the magnetization of the iron core.

*Magnetic circuits.* Because magnetic lines of force form closed loops, the path that the flux loops follow is called a magnetic circuit. Electrical circuits and magnetic circuits have many similarities. The force that produces a flow of electrons in an electrical circuit is the electromotive force (EMF). In the magnetic circuit, the force that produces the flux is called the magnetomotive force (MMF). Similarly, just as resistance opposes the flow of current in an electrical circuit, reluctance opposes the magnetic flux in a magnetic circuit. Also, just as conductance indicates the ease with which electrical current flows, permeability indicates the ease with which magnetic lines of force flow in a magnetic circuit.

**Exercises (203):**

Mark the following statements either true (T) or false (F) in the space provided. If a statement is false, explain why it is incorrect.

_____ 1. When a soft iron core is inserted into a solenoid, the lines of force will increase.

_____ 2. In a magnetic circuit the force that produces the flux is called the electromotive force.

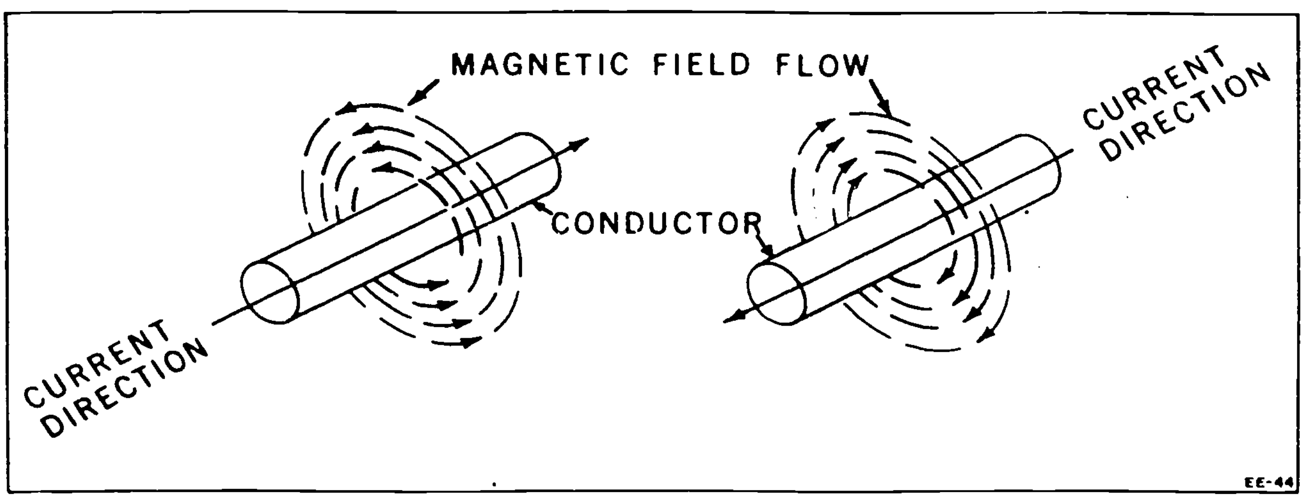


Figure 1-4. Direction of electron flow.

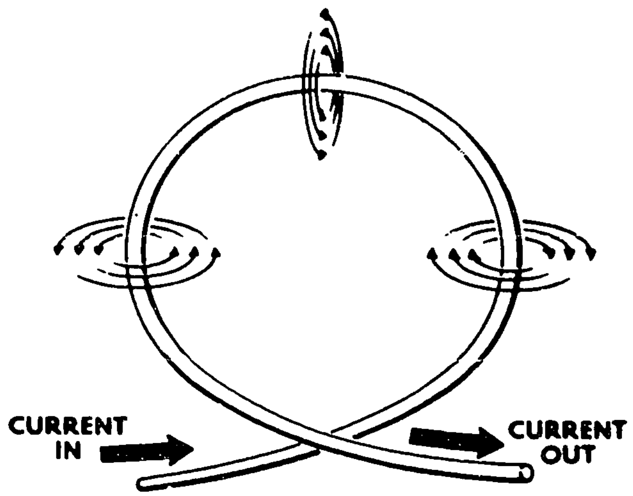


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Figure 1–5. Magnetic field about a loop.

_____3. When you place your left hand around a coil with the fingers pointing in the direction of electron flow, your thumb will point to the north pole.

_____4. When current is flowing through a single-loop conductor, the magnetic lines of force are concentrated to the outside of the loop.

_____5. The magnetic field's strength diminishes directly as the distance from the center of the conductor increases.

**204. Specify characteristics of direct and alternating current.**

**Dynamic Electricity.** Electricity in motion is called dynamic electricity. You previously learned that current flow is simply the movement of electrons through a conductor. Therefore, any time electrons flow through a conductor, dynamic electricity is at work. If the electrons move in one direction through the conductor, we have direct current (DC). If they move back and forth through the conductor at a specific interval, we have alternating current (AC).

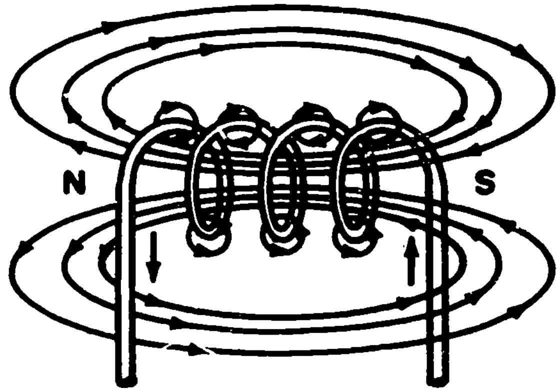


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Figure 1–6. Magnetic field produced by a coil.

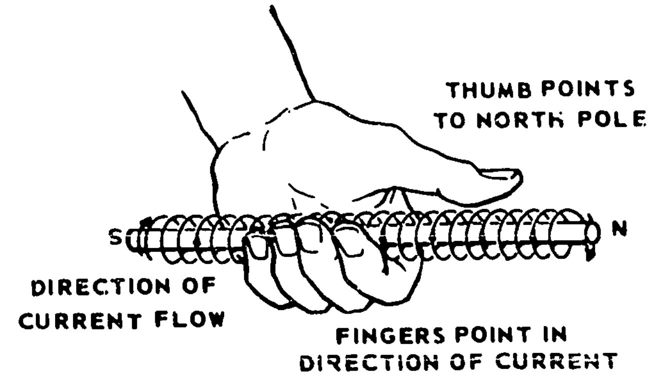


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Figure 1–7. Determining the polarity of a coil.

*Direct current.* Thus far in our discussion, electric current has been understood as a steady flow of electrons, caused by a voltage applied to a circuit. Furthermore, we said that current flows from a negative potential to a positive potential, or that there is a steady flow in one direction only. This type of current is known as direct current. There are many uses for which only direct current is suitable, such as battery charging, electroplating, and certain electronic circuits.

Certain electrical circuits make use of a particular type of direct current, called pulsating direct current. A pulsating direct current is obtained by using specially designed switches that alternately turn a direct current off and on, causing the current to flow in pulses. The auto mobile ignition coil circuit is a good example of pulsating direct current. Each time the ignition points close, a short pulse of direct current flows through the ignition coil. The current pulses always flow in the same direction.

*Alternating current.* A current which flows first in one direction and then reverses and flows in the opposite direction is an alternating current. One direction is called positive (+) and the other is called negative (−).

Alternating current cannot be obtained from batteries. It originates from a mechanical device called a generator or alternator.

**Exercises (204):**

1. Define direct current.

2. Define alternating current.

## 1-2. DC Circuits

In order for current to flow, two things are essential: there must be a source of electrical pressure (voltage), and there must be a complete circuit. The source of voltage may be a battery, a generator, or some other device. The complete circuit requirement means that there must be a complete path from the negative terminal, through the load, and back to the positive terminal of the source. The complete path should allow the electrons to flow freely to the load, do their work in the load, and then move freely back to the source without straying off into other loads or doing any unnecessary work. In this section, we will discuss the relationship of voltage, current, and resistance, and the application of Ohm's law in solving DC circuit problems.

**205. Identify the relationship of resistance, current, and voltage, and solve given DC series circuit problems using Ohm's law.**

**Ohm's Law.** There is a definite relationship between the voltage, current, and resistance of any circuit or part of a circuit. If the voltage is increased, the current increases proportionately; if the resistance is increased, the current decreases proportionately. We will discuss the basic law on which this relation is based. We use the law to compute quantities of voltage, current, and resistance in a basic electrical circuit.

A German scientist, Ohm, developed a law for the quantities of a circuit as follows: 1 volt is the pressure required to force 1 ampere of current through a resistance of 1 ohm. Ohm's law, simply stated, is as follows: "For any circuit or part of a circuit, the current in amperes is equal to the EMF in volts divided by the resistance in ohms." This means that if the voltage and resistance are known, the current may be determined by dividing the voltage value by the resistance. The equation below expresses this relationship:

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}}$$

Also, the values of voltage and resistance can be found if any two values are known. The following equations show this:

$$\text{Resistance} = \frac{\text{voltage}}{\text{current}}$$

$$\text{Voltage} = \text{current} \times \text{resistance}$$

Using the symbols for current (I), voltage (E), and resistance (R), Ohm's law can be stated as follows:

$$E = I \times R; I = \frac{E}{R}; R = \frac{E}{I}$$

If you look at figure 1-8, item A, you will see the Ohm's law circle. It is very helpful to remember the above equations.

An example of the application of the Ohm's law formula is as follows:

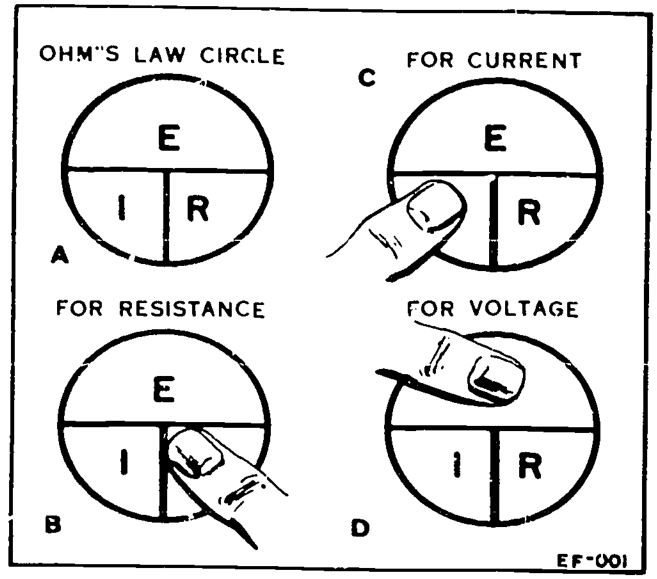



Figure 1-8. Ohm's law circle.

A circuit has an applied voltage of 120 volts and a resistance of 20 ohms. To find the current flow, simply apply Ohm's law as follows:

$$\frac{\text{E of 120 volts}}{\text{R of 20 ohms}} = \text{I of 6 amperes}$$

If a circuit has an applied voltage of 120 volts and a current flow of 2 amperes, the resistance is determined by the following application of Ohm's law:

$$\frac{\text{E of 120 volts}}{\text{I of 2 amperes}} = \text{R of 60 ohms}$$

To find the applied voltage of a circuit if the current and resistance are known, find the product of the current and resistance as follows:

$$\text{I of 2 amperes} \times \text{R of 60 ohms} = \text{E of 120 volts}$$

Application of Ohm's Law to Direct Current Series Circuits. In any practical circuit, certain components are necessary. For a basic series circuit, the components required are a source of power, conductors, a fuse or other protective device, a switch, and a unit of resistance.

A series circuit is defined as "a circuit which has only one path of current flow." In other words, in a series circuit the units are connected one after another so that the circuit current must flow through each unit. Figure 1-9 shows the arrangement of a series circuit.

Each electrical circuit has certain operating characteristics. The three characteristics of a series circuit are as follows:

- The total resistance is the sum of the individual resistors.
- The same current flows in each part of the circuit.
- The applied voltage will divide among the resistors according to their resistance.

To apply the characteristics of a series circuit, consider the circuit in figure 1-10. It has a 120-volt source of power,

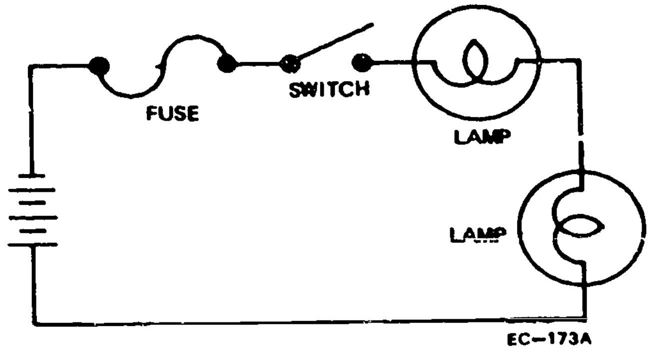



Figure 1–9. Arrangement of units in a series circuit.

a fuse, a switch, and two 30-ohm resistors in series. Since the total resistance of a series circuit is equal to the sum of the resistors, then the total for this circuit is 30 ohms plus 30 ohms, or a total of 60 ohms. Knowing the total voltage (120 volts) and the total resistance, we can now find the total current flow by the use of Ohm's law. Using the equation E/R = I, the problem is solved as follows:

$$\frac{120 \text{ volts}}{60 \text{ ohms}} = 2 \text{ amperes}$$

We find that 2 amperes of current will flow in the circuit when the switch is closed. Since the same current flows in each part of a series circuit, a current of 2 amperes will flow through each of the two resistors. To see how the voltage divides among the resistors, use Ohm's law again. At each resistor of 30 ohms, we now have a current flow of 2 amperes. To solve for the voltage used at each resistor (voltage drop), use the equation I × R = E as follows:

2 amperes × 30 ohms = 60 volts

Note that this is the same for each resistor. This is because the resistance is the same in both. Figure 1-11 shows how voltage divides among unequal resistors in a series circuit. Note that the unit with the most resistance uses most of the voltage.

**Exercises (205):**

1. What is the relationship of the current to the voltage and resistance in a DC circuit as given in Ohm's law?

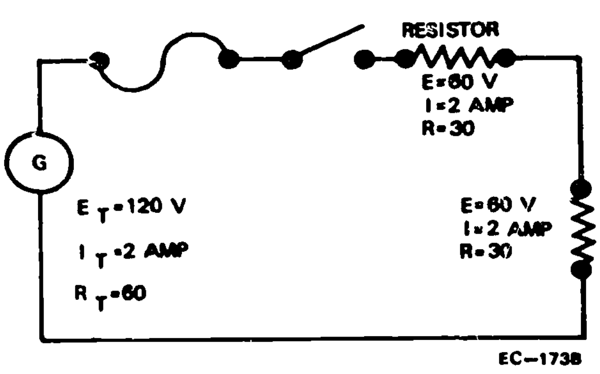



Figure 1–10. Series circuit with equal resistors.

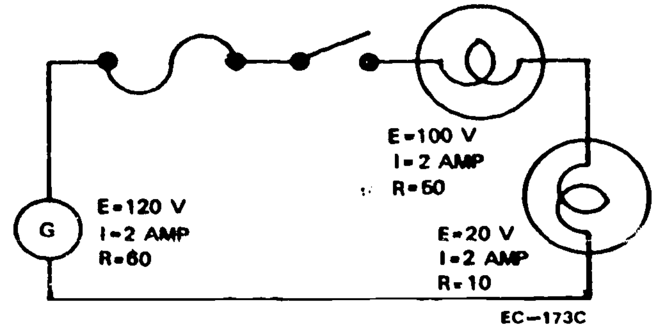



Figure 1–11. Series circuit with unequal resistors.

2. Show the Ohm's law equation and the solution to the following problems:
   a. Voltage = 90, current = 30, R = ?
   b. Voltage = ?; current = 2; and resistance: $R_1 = 7$, $R_2 = 5$.
   c. Voltage = 24; current = ?; resistance: $R_1 = 10$, $R_2 = 8$, $R_3 = 6$.

3. Compare the relationship of resistance, current, and voltage of a DC series circuit.

**206. From given information, solve DC parallel and series- parallel circuit problems.**

**DC Parallel Circuits.** Nearly all power circuits and interior lighting circuits are parallel; therefore, you must throughly understand parallel circuits. Parallel circuits, sometimes called multiple or shunt circuits, are circuits in which the components (units) are arranged in such a manner that the current divides between them. Thus, there are as many paths for the current to follow as there are conductors. Unlike a series circuit, a parallel circuit has two or more paths for current to flow.

If you examine figure 1-12, it is apparent that the same voltage that is applied to resistor R1 is also applied to R2 and R3. This is true because the corresponding points of each resistor are connected to the same points, "A" and "B," and the same difference of potential must exist between these points for all three resistors. This illustrates the first law of a parallel circuit. This law states: In a parallel circuit the same voltage is applied across each element.

If an additional path is provided for current to flow in a circuit, the total current in the circuit must be the original

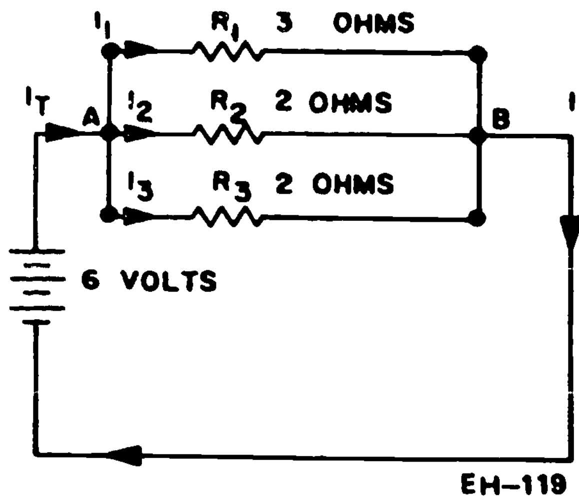



Figure 1-12. Parallel circuit.

plus that of the additional path. In figure 1-12, if only R1 is connected to the 6-volt source, it can be determined by Ohm's law (I = E/R) that the current is 2 amperes (6 divided by 3). When R2 is added, the same voltage is applied to it as was applied to R1. The current through R2 must equal 3 amperes (6 divided by 2). The total current flowing from the source is now 5 amperes (2 + 3). When R3 is added, the total current is then 8 amperes (2 + 3 + 3). From these results, this rule of a parallel circuit may be stated: The total current in a parallel circuit is equal to the sum of the current flow in the individual branches.

When the total current in the circuit and the applied voltage are known, the joint or combined resistance may be calculated by use of Ohm's law (R = E divided by I). The total resistance is 0.75 ohms (6 divided by 8). From this result, another rule for parallel circuits may be stated. The joint resistance of a parallel circuit is equal to the applied voltage divided by the total current. Compare the joint resistance with the individual resistance of R1, R2, or R3. Joint resistance, in this case, equals .75 ohms and is less than either R1, R2, or R3. Always remember that in a parallel circuit the combined or joint resistance of the circuit is less than the resistance of the smallest element.

It would be very helpful for you to establish the following laws of a parallel circuit firmly in your mind:

- In a parallel circuit, the same voltage is applied across each element.
- The total current in a parallel circuit is equal to the sum of the currents in the individual branches.
- The joint resistance of a parallel circuit is equal to the applied voltage divided by the total current and is always less than the smallest individual resistance.

When the total current is unknown and several resistors of equal value are connected in parallel, the combined or joint resistance can be found by dividing the resistance of one piece of equipment by the number of pieces connected in parallel. For example, if two 10-ohm resistors are connected in parallel, the joint resistance offered by the combination is 5 ohms (10 divided by 2). If three 12-ohm resistors are in parallel, the joint resistance is 4 ohms (12 divided by 3). If five 10-ohm resistors are in parallel, the total resistance is 2 ohms (10 divided by 5). To state this as a rule, The joint resistance of equal resistances connected in parallel is equal to one resistance divided by the number of connected resistances.

All equipment used in electrical circuits does not have the same resistance. Therefore, when different pieces of equipment are connected in a parallel circuit, they do not draw the same current. Two unequal resistors connected in parallel are shown in figure 1-13. In this case, the current through the parallel connected resistor A is $I_A = E/R_A = 24/12 = 2$ amperes. The current through resistor B is $I_B = E/R_B = 24/4 = 6$ amperes. The current is equal to the sum of the currents in the branches ($I_T$ = 6A + 2A = 8 amperes). Ohm's law will give the joint resistance offered by the current as $R_J = E/I_T = 24/8 = 3$ ohms.

The rule for equal resistors in parallel could not be used for this circuit because the individual resistors A and B are not equal in value. For such cases, another rule has been developed for the calculation of joint resistance. The joint resistance of two resistors in parallel is equal to their product divided by their sum. This rule as applied to the circuit in figure 1-13 is as follows:

$$R_J = \frac{\text{product}}{\text{sum}} = \frac{12 \times 4}{12 + 4} = \frac{48}{16} = 3 \text{ ohms}$$

This is the same answer found when applied voltage was divided by the total current.

The product-over-sum method may be applied to any two resistors in parallel, whether they are equal or not. It is the most commonly used method of determining the resistance of a parallel circuit. This method may be extended to include three or more unequal resistors in parallel. First, determine the resistance of two resistors in parallel; then combine the results of this calculation with one of the remaining resistances by additional application of the same rule. In each case, the result of the previous calculation is combined with the one of the remaining resistances and so on until the total or joint resistance has been determined. For example, consider the circuit shown in figure 1-14. In this circuit, three unequal resistors are connected in parallel. Apply the rule to resistors B and C as follows:

$$R_J = \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2 \text{ ohms}$$

Combine this result (2 ohms) with the remaining resistance A as follows:

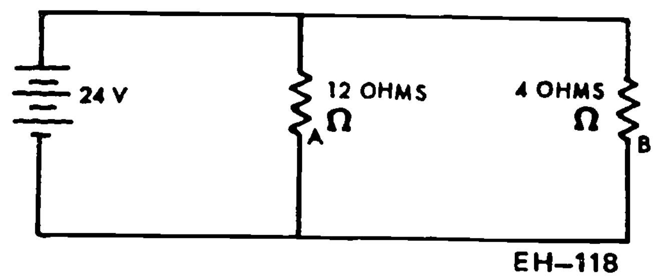



Figure 1-13. Two unequal resistors connected in parallel.

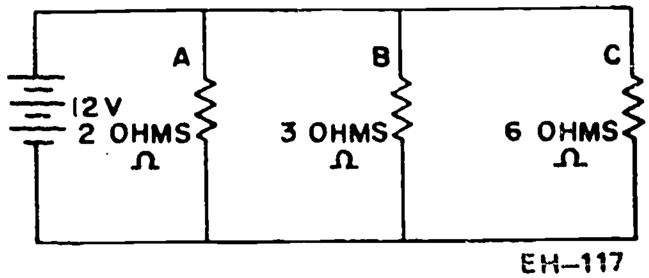



Figure 1-14. Three unequal resistors connected in parallel.

$$R_J = \frac{2 \times 2}{2 + 2} = \frac{4}{4} = 1 \text{ ohm}$$

This result ( 1 ohm) is the joint resistance of three resistors (A, B, and C) in figure 1-14.

There is another method of finding the joint resistance of several resistors in parallel. This method is known as the reciprocal method. As you have seen, the product- over-sum method can be used only with two resistors at one time. If as many as five or six resistors are in parallel, the arithmetic solution would be a lengthy procedure. The reciprocal method may be used to find the joint resistance of any number of resistors in one operation. The rule is stated as The joint resistance of a parallel circuit is equal to the reciprocal of the reciprocals of the individual resistances. This rule can be stated as a formula and applied to figure 1-14 as follows:

$$R_J = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$R_J = \frac{1}{\frac{1}{2} + \frac{1}{3} + \frac{1}{6}}$$

$$R_J = \frac{1}{.5 + .33 + .17}$$

$$R_J = \frac{1}{1} = 1 \text{ ohm}$$

If the joint resistance of only two resistors in parallel is required, the product-over-sum method is probably the easier to use. If the joint resistance of three or more resistors is required, the reciprocal method is better. When in doubt, the work can be proved by assuming an applied voltage and using Ohm's law to determine total current and resistance.

**Series-Parallel Circuits.** Series-parallel circuits consist of groups of parallel resistors in series with other resistors. Any leg of a parallel group may consist of two or more resistors in series. Series-parallel circuits may be analyzed by the rules applied to simple series circuits and simple parallel circuits. To make this application. the series-parallel circuit is reduced to an equivalent, simplified circuit. Each group of parallel resistors is first replaced by its equivalent single resistance, and the entire circuit is then treated as a series circuit.

When this is applied to the circuit in figure 1-15, the first step is to reduce the two parallel resistors B and C to an equivalent single resistance. Since B and C are equal, divided 10 by 2. This gives 5 ohms as the joint resistance of the parallel branch. The circuit is now a simple series circuit of two 5-ohm resistors. The total resistance is obtained by adding the resistance A to the equivalent of B and C. This gives 5 plus 5, or 10 ohms, as the resistance of the entire circuit. Knowing this, the total current is calculated by applying Ohm's law as follows:

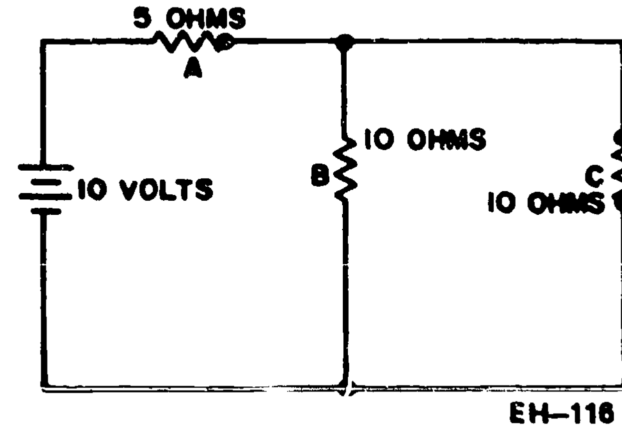



Figure 1-15. Simple series-parallel circuit.

$$I_T = \frac{E_T}{R_T} = \frac{10}{10} = 1 \text{ ampere}$$

This 1 ampere flows through resistor A, giving a voltage drop of 5 volts. Since the two parallel resistances have the same value, the 1 ampere of current divides equally between the two. The IR drop across B equals 1/2 × 10, or 5 volts, and across C equals 1/2 × 10, or 5 volts also. This demonstrates the rule that each element of a parallel circuit is supplied the same voltage. By following one complete path around the circuit, it can be shown that the sum of the voltage drops is equal to the applied voltage. Starting from the positive side of the battery, there is a 5-volt drop in resistor A, another 5-volt drop in resistor B, and thus back to the battery. Care must be taken to follow only one path at a time in tracing through a circuit.

The example just presented was of a very simple nature. In figure 1-16, we have a series parallel circuit of a less simple nature; and the solution will involve more steps, as we shall see. The steps in the solution of circuit A, figure 1-16, are as follows:

*a.* Combine resistor X and Y of circuit A, and they can be represented by resistance N of circuit B. Circuit B is the equivalent circuit of circuit A in figure 1-16. X and Y are equal and in parallel; therefore, their joint resistance is as follows:

$$N = \frac{10}{2} = 5 \text{ ohms}$$

*b.* Combine resistors W, N, and Z (circuit B of fig. 1-16) into a simple resistor M of circuit C in figure 1-17. W, N, and Z are in series; therefore, the resistance of M equals 15 ohms (5 + 5 + 5 = 15).

*c.* Combine resistors O, K, and M (of circuit C in fig. 1-17) into a simple resistance P of circuit D of figure 1-17.

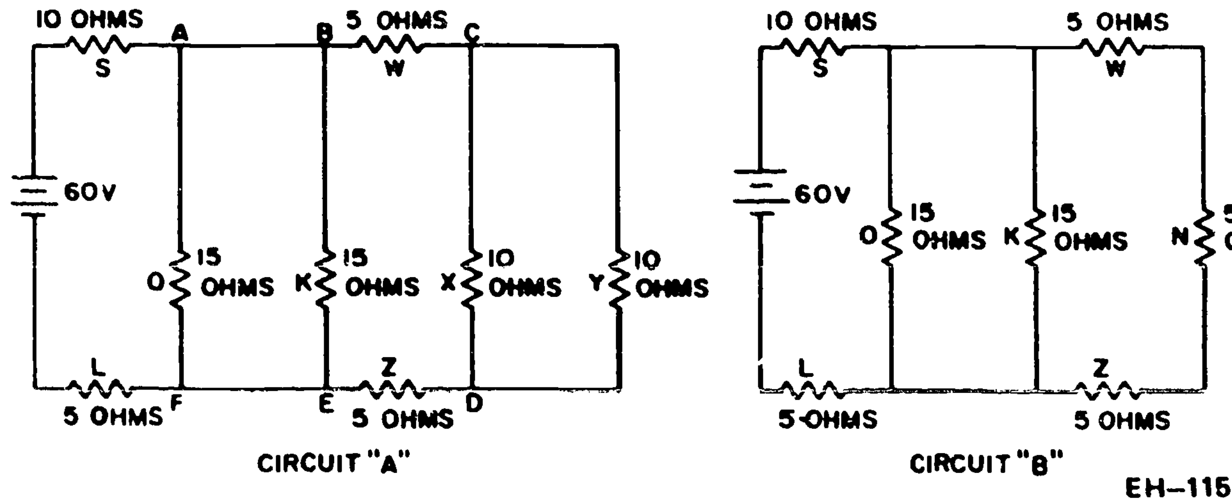



Figure 1-16. Solving series-parallel circuits by simplification.

Since resistors Ok, K, and M are equal and in parallel, they can be treated as follows:

$$P = \frac{15}{3} = 5 \text{ ohms}$$

*d*. Combine resistors S, P, and L (circuit D, fig. 1-17), which are in series. The combined or joint resistance ($R_J$) of the whole circuit equals 20 ohms (10 + 5 + 5).

*e*. Find the total current ($I_T$) of the circuit as follows:

$$I_T = \frac{E}{R_T} = \frac{60}{20} = 3 \text{ amperes}$$

*f*. Find the voltage drop across S (circuit C, fig. 1-17) as follows:

$$E_S = I_T \times R_S = 3 \times 10 = 30 \text{ volts}$$

*g*. Find the voltage drop across L (circuit D, fig. 1-17) as follows:

$$E_L = I_T \times R_L = 3 \times 5 = 15 \text{ volts}$$

*h*. Find the voltage drop across equivalent resistance P (equivalent of O, K, M, circuit C) as follows:

$$E_P = E_T - E_S - E_L = 60 - 30 - 15 = 15 \text{ volts (circuit C, fig. 1-17)}$$

The voltage drop across each parallel branch is equal. Find the current in resistor O as follows:

$$I_O = \frac{E_O}{R_O} = \frac{15}{15} = 1\text{A}$$

*i*. At point A of circuit A, figure 1-16, there are two paths for the current flow. In a parallel circuit, the total current equals the sum of the currents in the branches.

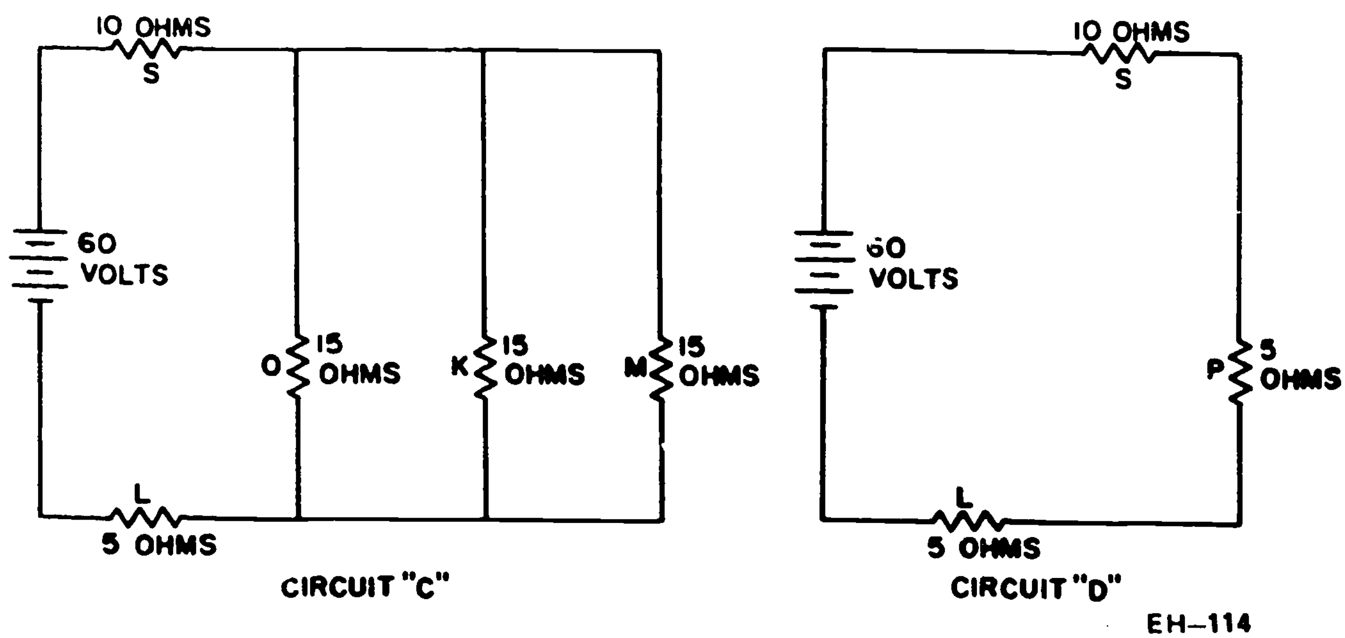



Figure 1-17. Solving series-parallel circuits by simplified equivalent circuits.

Therefore, the current flowing from point A to point B equals $I_T - I_O$, or $3 - 1 = 2$ amperes.

*j.* The voltage drop across parallel resistors is equal, so the voltage drop across K is 15 volts; the current

$$(I) = \frac{E}{R}, \text{ or } \frac{15}{15} = 1 \text{ ampere}$$

*k.* Since a current of 2 amperes flows from point A to point B and 1 ampere of current flows through resistor K, the current through W must be 1 ampere (2 - 1).

*l.* At C the current divides again. Since the resistances X and Y are the same, the current divides equally, with 1/2 ampere going through each resistor.

*m.* Voltage across X and Y will be the same ($1/2 \times 10 =$ 5 volts).

*n.* At C to D of circuit A (fig. 1-16) the two currents of 1/2 ampere join, and 1 ampere flows through Z. Voltage drop across Z is 5 volts ($1 \times 5$).

*o.* At point E the current through Z and K join, and 2 amperes ($1 + 1$) flow through E to F.

*p.* At point F the current flowing through O joins the current flowing from point E to F, and 3 amperes ($1 + 2$) flow through L. Recall that this 3 amperes is equal to the total current.

As stated before, there is a definite relationship between current, voltage, and resistance of any circuit. You should know how to compute for either of these with the aid of Ohm's law.

**Exercises (206):**

1. What should be the first step to solve the circuit in figure 1-15?

2. What is the rule pertaining to the total current in a parallel circuit?

3. How would you compute the voltage drop across resistor S in circuit C of figure 1-17?

4. When solving a series-parallel circuit, what should you do first to the circuit?

**207. Identify power terms and solve problems concerning power.**

**Terms Used in Relationship to Power.** You will find it of value to learn the meanings of the following terms commonly used in electric circuits: force, work, energy and power.

*a.* FORCE is defined as that which produces, or tends to produce, a change in motion of a body. In electronics, electrical force causes electrons to move from one point to another. The unit of force is the dyne.

*b.* WORK is the production of motion against a resisting force. In electronics, electromotive force causes electrons to move against the opposing force offered by the resistance in a circuit. When an ampere of current flows through a resistance of 1 ohm for 1 second, a joule of work is done.

*c.* ENERGY is the capacity or ability to do work. Energy that is due to motion of matter is called kinetic energy, whereas energy that is due to the position of matter is called potential energy. As an example, the electrons on a negatively charged body possess potential energy with respect to a less negatively charged body, because these electrons would flow if the two bodies were connected by a conductor. The electrons moving along the conductor connecting the two bodies possess kinetic energy because such electrons are in motion. Energy may be dissipated in such forms as heat, light, and motion. It may be transformed from one form to the other, as is done in producing electron flow by mechanical or chemical means. Since energy is the capacity to do work, energy and work have the same unit (joule).

*d.* POWER is the rate of doing work and is abbreviated by the symbol "P." Forcing electrons through a resistor requires work, and energy is expended in the resistor in the form of heat. If this heat is not too great, it can be radiated and will not damage the resistor. If it is excessive, it cannot be radiated as quickly as it is generated; consequently, the resistor becomes too hot and burns out. As a precaution against excessive heating, a resistor is specified as having a certain power rating, meaning that no more than a specified current (given number of electrons per second) can be allowed to flow through the resistor without damaging it. Electrical power is the rate that electrons are forced through resistance by electromotive force (EMF).

**Power in DC Circuits.** The unit of electrical power is the watt. One watt of power is present in a 1-ohm resistor in which a current of 1 ampere is flowing; in other words, a resistor consuming 1 joule of energy per second. A larger unit of power is the kilowatt, which equals 1000 watts. The power dissipated by some resistors is on the order of one-tenth of a watt. However, some resistors dissipate as much as 50 watts. A horsepower, the unit for measuring mechanical power, is equivalent to 746 watts.

Since power is the rate of doing work or consuming energy, the length of time power is used is the true measure of energy consumed. It is common practice to purchase electrical energy by watt-hours (watt $\times$ hours). This unit is so small that the unit kilowatt-hours, equal to 1000 watt-hours, is used. As an example, let's take an ordinary 100-watt lamp bulb, as found in your home. A 100-watt bulb requires 100 watts of power for proper operation and consumes 100 watt-hours of energy in 1 hour. In terms of kilowatt-hours, the lamp uses 0.1 kilowatt-hour in 1 hour. In 10 hours of operation, the bulb would consume a kilowatt-hour of energy. In 24 hours, the bulb would consume 2.4 kilowatt-hours.

To determine the power in a simple DC electrical circuit, the power formula $P = E \times I$ may be used. For example, a

circuit with an applied voltage of 120 volts and a current flow of 10 amperes will consume 120 × 10 = 1200 watts. The circuit in figure 1-18 shows a circuit with two lamps in series. Each lamp has a resistance of 60 ohms, and the circuit has an applied voltage of 120 volts. Note that each lamp is consuming 60 watts of power. In other words, they are 60-watt lamps.

You can also find the power in a DC circuit if you know the resistance (R) with the use of the following formulas:

$$P = \frac{E^2}{R}$$

$$P = I^2R$$

**Exercises (207):**

1. Match the term in column A with the statement in column B.

| *Column A* | *Column B* |
|---|---|
| ______(1) Force. | a. The ability to do work measured in joules. |
| ______(2) Work. | b. The production of motion against a resisting force measured in joules. |
| ______(3) Energy. | c. The rate of doing work measured in watts. |
| ______(4) Power. | d. That which produces a change in motion of a body measured in dynes. |

2. How is power computed in a DC circuit with only resistance and current known?

3. In a parallel circuit having four equal lamps, with an applied voltage of 120 volts and a total current flow of 4 amperes, what is the power consumed at each lamp?

## 1-3. AC Circuits

In order to understand how electrical equipment is connected and how it functions, it is necessary to

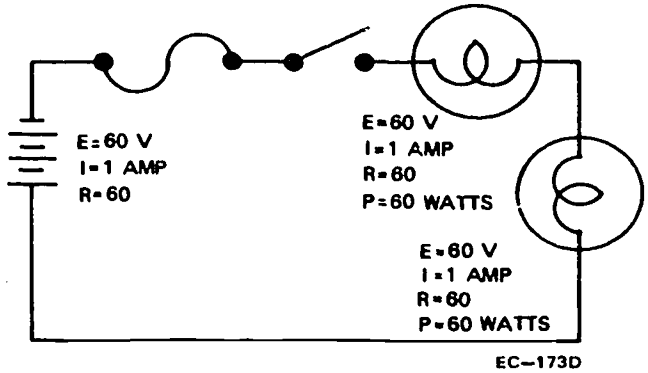



Figure 1-18. Two 60-watt lamps in series.

understand how current flow, voltage, and resistance are related in the circuit. We have discussed this relationship in DC circuits; now we will discuss it in AC circuits.

**208. Given information on the fundamentals of alternating current, relate the description or function to the appropriate term, tell how electrons travel, and specify the use of hertz.**

**Fundamentals of AC.** Electrical current flow consists of electrons moving in a circuit. Since the electron is negatively charged, it is repelled at the negative end of the circuit and attracted to the positive point. Therefore, it travels from negative to positive. In the direct current circuit it moves in one direction only. In the alternating current circuit, its polarity is changing at regular intervals. This causes the current to flow in one direction and then in the opposite direction. The alternations in current flow are shown in figure 1-19. The solid arrows indicate the direction of current flow during the positive alternation, and the dotted arrows show the current flow during the negative alternation. Since the current flow is continuously alternating in its direction flow, it is called alternating current.

***Cycle and Frequency.*** When an AC generator completes a positive and a negative alternation, it has completed one electrical cycle. It is represented by the symbol ~. The number of times each cycle occurs in 1 second is called frequency. This is now expressed as hertz per second or simply by hertz. We now say that the frequency of the power system is 60 hertz.

NOTE: The term "hertz" has been adopted recently in recognition of Heinrich Rudolph Hertz, a German physicist. He discovered in his electrical experiments that electricity can be transmitted in electromagnetic waves at the speed of light.

The frequency of a system was formerly expressed in cycles per second. The waveforms of alternating current are shown in figure 1-20. This is usually referred to as a sine wave. The term "sine wave" is derived from the operation of a generator. It is so named because the alternator output voltage at any given point on the wave is the product of the sine of the rotor angle and the peak voltage.

The frequency of the AC generator voltage output depends upon the speed of rotation of the rotor and the number of pairs of poles. With a given number of poles, the faster the speed of rotation of the rotor, the higher the frequency will be; and, conversely, the lower the speed of rotation, the lower the frequency. When a rotor has turned through an angle so that two adjacent rotor poles (paired north and south poles) have passed one winding, the voltage induced in that winding will have varied through one complete cycle. Therefore, for a given frequency, the more pairs of poles there are, the lower will be the required speed of rotation.

A 2-pole generator must rotate at twice the speed of a 4-pole generator for the same frequency of generated voltage. The frequency of the generator in hertz can be determined by the following formula:

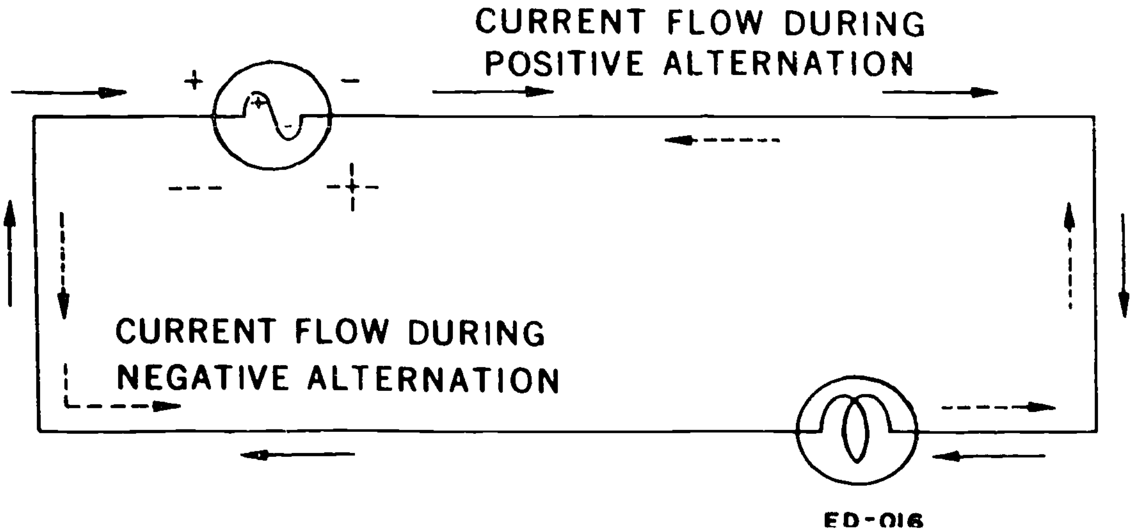



Figure 1–19. Electron flow in an AC circuit.

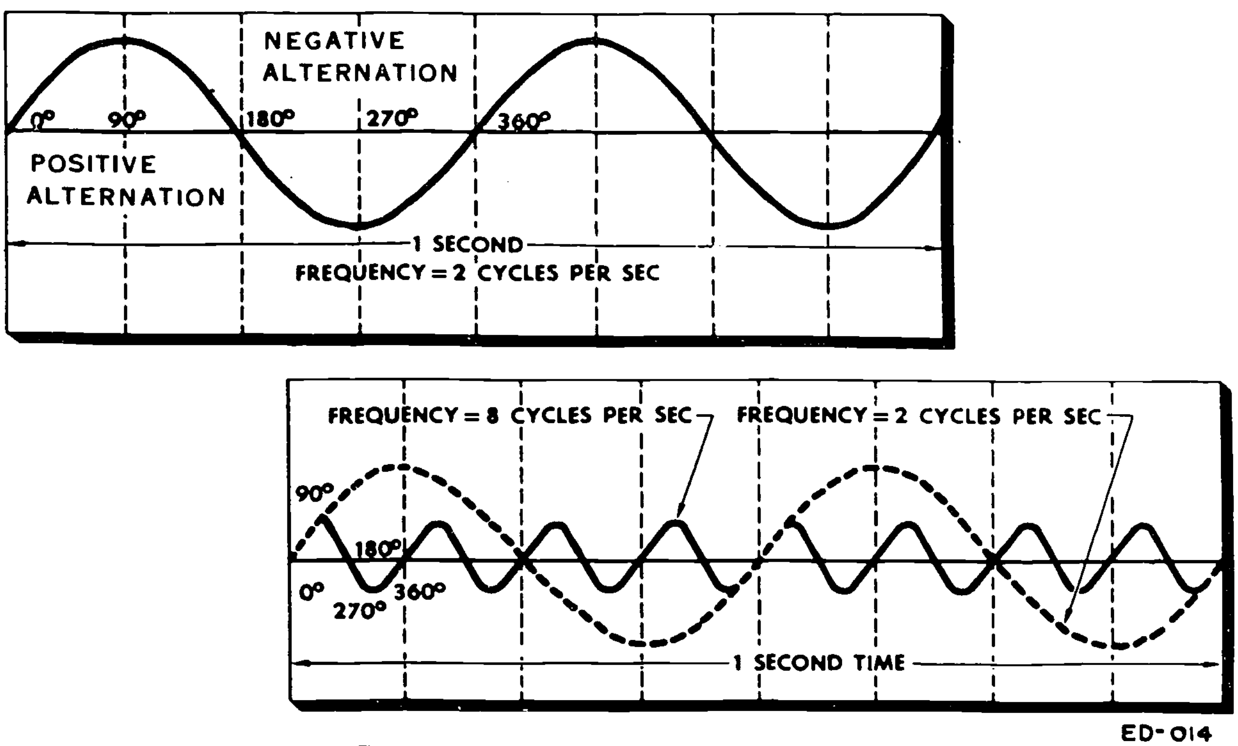



Figure 1–20. Relationship of frequency and cycles in AC.

$$f = \frac{P}{2} \times \frac{N}{60} = \frac{PN}{120}$$

where P is the number of poles and N the speed in rpm. For example, a 2-pole, 3600-rpm generator has a frequency of $\frac{2}{120} \times 3600 = 60$ hertz; a 4-pole, 1800-rpm generator has the same frequency; a 6-pole, 500-rpm generator has a frequency of $\frac{6}{120} \times 500 = 25$ hertz; and a 12-pole, 4000-rpm generator has a frequency of $\frac{12}{120} \times 4000 = 400$ hertz.

***Alternating current values.*** Four values must be considered when we discuss alternating current and voltage. We will take them in the following order: the maximum or peak value, the instantaneous values, the average value, and the effective value. These are shown in the sine-wave form in figure 1-21. We will also take a brief look at the way they affect the power in an AC circuit.

*Maximum or peak value.* The maximum or peak value is indicated as the highest voltage or the highest current reached on either the positive alternation or the negative alternation. It occurs when a particular generator coil is cutting the maximum (greatest) number of flux lines. No greater amount of current or voltage can be induced by this magnetic field in this coil. Because this characteristic of generator voltage output is most often called peak, we'll use that term from here on and drop the term "maximum" from our discussions.

*Instantaneous values.* The instantaneous values are between zero and the peak value in either the positive or negative alternation. Instantaneous value is simply the value of the alternating current or voltage at one particular instant. It may be the same as the peak value if the selected instant is at the time the voltage or current stops increasing and starts decreasing, or it could be zero if the selected instant is the time during which the polarity of the voltage is changing. For this reason, in alternating current the peak value of voltage or current cannot be used in solving for power consumption as it can be in direct current.

*Average value.* The average value in alternating current is the average of all the instantaneous values during one

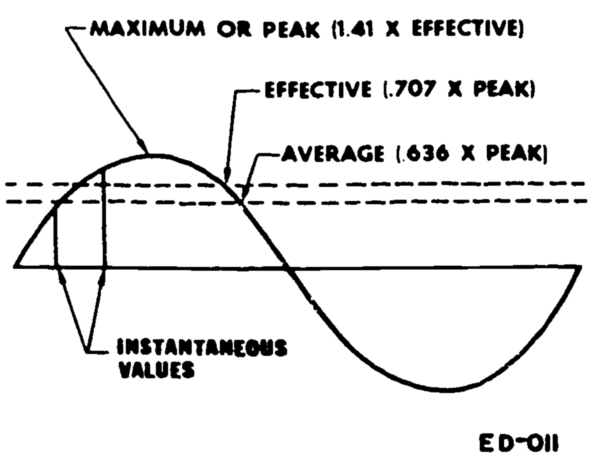



Figure 1-21. AC values.

alternation. Except for being a mathematical viewpoint, it is of no great significance since it is merely a numerical average of all the sine values for all the angles. Average value has been computed to be equal to 0.636 times the peak value. It is always this ratio.

*Effective value of current or voltage.* In alternating current, any value given for current or for voltage is assumed to be effective value unless otherwise specified. Therefore, in your work you will be dealing only with effective values of voltage or current. You should not confuse this value, as people often do, with the "average value" because the "effective value" is the actual rating of the useful power available to do work. Since it is the actual rating of the useful power to do work, perhaps a discussion of what is meant by the term is in order.

As you know, in any DC circuit the voltage across the circuit and the current through the circuit have certain magnitudes. You also learned earlier that these are determined by the actual values of the voltage and the resistance present in the circuit. It should be clear, then, why the term "effective value" had no particular significance in our discussion of DC circuits. After all, if 10 volts or 1000 volts is applied to a DC circuit, the effective DC voltage is obviously 10, or 1000 volts. (If this statement is puzzling, it is suggested that you go back and read those pages dealing with DC circuits.) But, in AC circuits, since the instantaneous values of current or voltage vary, there must be some basis on which to judge them. The basis used is direct current; therefore, when the voltage or current in an AC circuit is in phase, the effective values of voltage or current are expressed as values of DC voltage or current. In other words, the effective value of alternating current is the same value as direct current in the same circuit that would cause the same amount of electrical energy to be dissipated or produce an equal heating effect.

To get back to our sine-wave voltages for a moment, since AC power is of a sine-wave nature, it is not necessary to resort to any experimental computations to arrive at its effective value. It has been proven mathematically that for sine-wave current or voltage, the effective value is always equal to 0.707 times the peak value. As an example, let's say that 10 volts of AC power is applied to a circuit. The effective voltage present would then be equal to 0.707 times 10 volts, or 7.07 volts. Because this constant is also true regarding current, if the current in this same circuit measured 10 amperes peak, the effective current would be 7.07 amperes. The effective value of either current or voltage in an AC circuit is, therefore, equal to 0.707 times the peak value ($E_{eff} = .707\ E_{peak}$).

The effective value is also called the root-mean-square or RMS value. Since the term "RMS value" is so often used in electrical specifications, let's find out how this particular figure above—this constant—is arrived at, and why it is referred to as the RMS.

The effective value of an EMF is equal to the square root of the average of the sums of the squares of the instantaneous values that make up a cycle. As is indicated above, the effective EMF is represented by the symbol $E_{eff}$. Its relation to the peak emf is expressed in the formula:

$$E_{eff} = \frac{E_{peak}}{\sqrt{2}}$$

or

$E_{eff} = 0.707\ E_{peak}$

and, for current,

$I_{eff} = 0.707\ I_{peak}$

So that these values for sine-wave current and voltage can be arrived at without lengthy mathematical computations, a list of constants has been calculated. The relationship between these values applies only to sine-wave AC for both voltage and current.

The other values, which we have discussed in these few paragraphs, follow along in line. Thus, the peak value is equal to 1.41 times the effective value; the average value is equal to 0.636 times the peak value; and, conversely, the peak value is equal to 1.57 times the average value.

*Apparent power*. While we are on the subject of values, it might be well to discuss what is known as apparent power, because the apparent power in an AC circuit is equal to the product of the effective (or the rms) values of voltage and current. This product, however, is not equal to the true power except when the voltage and current are in phase.

It might be well to remind ourselves that apparent power is expressed in kilovolt-amperes. Thus, an expression of a quantity of kilovolt-amperes (KVA) is a measurement of the apparent power of an AC electrical system. The quantity kilovolt-ampere is derived by dividing the number of volt amperes by 1000. Apparent power, or volt-amperes, is of considerable importance because it is the volt-amperes, not volts, that determine the operating limits of an AC generator.

***Inductive reactance and the "henry."*** Inductance is indicated by the letter L—its unit of measurement is called the henry. In an AC circuit containing inductance, there is opposition to the flow of current in addition to the resistance normally present. The extent of this opposition depends on two things, the frequency of the applied voltage and the amount of inductance that is present in the circuit. This opposition is known as inductive reactance. Inductive reactance is identified by the symbol $X_L$ and is measured in ohms. The formula used for finding inductive reactance is:

$X_L = 2\pi\ (f \times L)$

where

$2\pi = 6.28$

f = frequency in hertz and

L = inductance in henrys

Because of the nature of a counter EMF, there is no actual loss of electrical energy. Therefore, even though inductive reactance is in opposition to alternating current flow, its result is not loss, but it does require a greater applied voltage to overcome this additional opposition. Because of the opposition by inductive reactance, current lags the voltage in an AC circuit. However, you will quickly see, if you multiply the instantaneous values of the voltage and current together when this out-of-phase condition exists, that the power output is greatly diminished. Also, if the circuit is purely inductive, the current will lag the voltage by 90°.

In DC circuits, resistances in series are added to find the total resistance in the circuit. In an identical manner, the total reactance in an AC circuit is found by adding the individual reactances. Let's illustrate this:

$(X_L)_T = (X_L)_1 + (X_L)_2$

In the same way, to find the total reactance of inductors in AC parallel circuits we can apply the following formula:

$$(X_L)_T = \frac{1}{\frac{1}{(X_L)_1} + \frac{1}{(X_L)_2} + \frac{1}{(X_L)_3} + \frac{1}{(X_L)_4}}$$

$(X_L)_T$ = total reactance

$(X_L)_1$, etc. = individual reactances

***Capacitance.*** While inductance is the property of a coil in an AC circuit, capacitance is the property of a capacitor. The unit of capacitance is called the farad. A capacitor is a device having the ability to store, or hold, a charge of electricity. When placed in an AC circuit, it stores electricity on one alternation (1/2 cycle); when the current is at the point of reversing polarity on the other alternation, the capacitor discharges in the original current direction to continue the flow until discharged. It then recharges and repeats its action in the other direction on the second alternation. Figure 1-22 is a simple visual explanation of the characteristics of an AC circuit containing a capacitor. As you can see, the plate of the capacitor alternately changes polarity.

In a circuit where there is only capacitance, the current leads the impressed voltage. This is in direct contrast with a circuit containing pure inductance where the current lags the voltage.

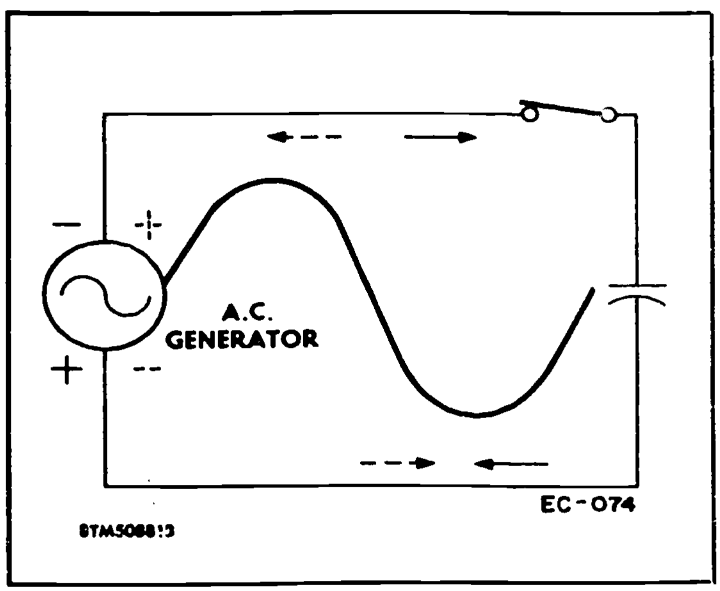



Figure 1-22. Capacitance in an AC circuit.

*Capacitive reactance.* Capacitance, like inductance, offers opposition to the flow of alternating current. This opposition is called capacitive reactance and is measured in ohms, just as inductance is measured, but it is designated by the symbol $X_C$.

$$X_C = \frac{1}{2\pi \times f \times C}$$

where

$2\pi = 6.28$

f = frequency in hertz

C = capacitance in farads

*The effects of inductive and capacitive reactance.* Let's go back for a moment to the formula for inductive reactance and further compare it with this formula for capacitive reactance.

By comparing the two formulas, we can see that while $X_L$ is directly proportional to the frequency and inductance, $X_C$ is inversely (the exact reverse) proportional to the frequency and capacitance. Another way of saying the same thing is that $X_L$ increases as the frequency and inductance increase, and $X_C$ decreases as the frequency and capacitance increase. This simply means that since inductive and capacitive reactances act in opposite directions, one can be used to cancel out the effects of the other. How is it accomplished? We know that if a power circuit contains a large value of inductance, it will cause the current to lag the voltage. By the same token, we know that too much capacitance will cause the current to lead the voltage. Therefore, by adding just enough capacitance to the circuit to counteract the effects of the inductance, we can bring the current and voltage back in phase. This is usually done in AC circuits and causes the apparent power and true power to be equal.

***Impedance.*** Impedance is the term used to signify the total opposition to the flow of AC in a circuit. It is the combined effect of the total reactance and the resistance. The total reactance is the difference between $X_L$ and $X_C$. The symbol for impedance is Z. Because it opposes current flow, it has the same unit of measurement as resistance—the ohm. This is more clearly shown in the impedance triangle in figure 1-23.

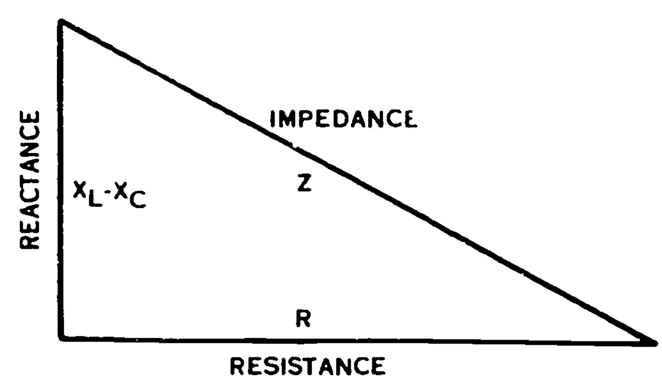



Figure 1–23. The impedance triangle.

**Exercises (208):**

1. How do electrons travel in a circuit?

2. Why do we use the term "hertz" instead of frequency?

3. Match the description or function in column B to the term in column A by placing the correct letter by the appropriate number.

*Column A*

_____ (1) Cycle.
_____ (2) Apparent power.
_____ (3) Inductance.
_____ (4) $X_L$.
_____ (5) Farad.
_____ (6) Capacitance in circuit.
_____ (7) Impedance.
_____ (8) Total reactance in an AC circuit.
_____ (9) Inductive reactance.
_____ (10) Frequency.
_____ (11) $\frac{P}{2} \times \frac{N}{60}$.
_____ (12) Maximum peak value.

*Column B*

a. Equal to the product of the effective values of voltage and current.
b. Symbol for inductive reactance.
c. Determined by the frequency and amount of inductance in the circuit.
d. Total opposition to the flow of alternating current.
e. Unit of capacitance.
f. Found by adding the individual reactance.
g. Number of times each cycle occurs in a second.
h. Causes the current to lead the voltage.
i. A complete positive and negative alternation.
j. Formula for determining frequency.
k. The property of a coil in an AC circuit.
l. Highest voltage or current reached during an alternation.

**209. Select the correct formula to be used in computing resistive, inductive, and capacitive circuits.**

**Problems in Alternating Current Circuits.** This discussion deals with Ohm's law as it relates to AC circuits; and, at the same time, it will be a resume of what we have learned concerning the peculiarities of AC circuits. Here, we will be working with simple mathematical equations for finding the various values peculiar to AC circuits. If you know these and understand them, you will have little trouble in understanding alternating current. It is a good idea for you to work these problems for yourself, even though the method and answers are shown. A complete manual, longer than this course, could be written about troubleshooting, but if you don't actually do the job, such a manual would be worthless.

Let's take our formula for impedance:

$$I = \frac{E}{Z}, Z = \frac{E}{I}, \text{ and } E = IZ$$

and, let's say we have a series circuit containing a lamp with 11 ohms of resistance connected across a source of voltage, shown in figure 1-24.

For the sake of comparison, we'll first find how much current will flow if 110 volts DC is applied and how much current will flow if 110 volts AC is applied. If you remember, the Ohm's law we discussed earlier gave us the formula:

$$I = \frac{E}{R}$$

In this case:

$$I = \frac{110}{11}$$

or

$I = 10$ amperes DC

If AC is applied, the formula is:

$$I = \frac{E}{Z}$$

where Z (impedance) is equal to R (resistance). By substituting:

$$I = \frac{110}{11}$$

and

$I = 10$ amperes AC

As you can see, this simple circuit contains resistance only, which brings up a point to remember: If a circuit contains resistance only, the current flow is the same regardless of whether the applied voltage is alternating or direct.

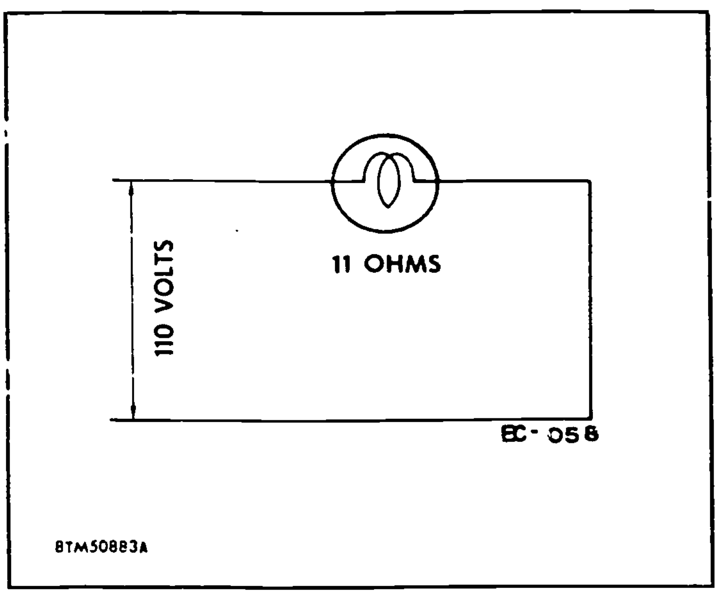



Figure 1–24. Resistance in an AC circuit.

*Inductive reactance*. Now, let's apply Ohm's law to an AC circuit containing inductive reactance, the symbol for which is $X_L$. The formula, then, should look like this:

$$I = \frac{E}{X_L},\ X_L = \frac{E}{I},\ \text{and } E = IX_L$$

Suppose we have an AC series circuit like that shown in figure 1-25, in which the inductance is 0.146 henrys and the voltage is 110 volts at a frequency of 60 hertz. Now, what is the flow of current in this circuit? First of all, the inductive reactance must be found. We know that the inductance as expressed in henrys is $L = 0.146$; by substitution in our formula for inductive reactance, we should have:

$X_L = 2\pi \times f \times L$

$X_L = 6.28 \times 60 \times 0.146$

$X_L = 55$ ohms

and to find the current,

$$I = \frac{E}{X_L}$$

$$I = \frac{110}{55}$$

$I = 2$ amperes

*Capacitive reactance*. In this same manner, to find the capacitive reactance and the current flow in a circuit, we would find the reactance first and then the current.

Let's assume that in another series circuit, as shown in figure 1-26, there is an impressed voltage of 110 volts at 60 hertz and that in the circuit there is a capacitor with a capacitance of 80 µF. Since 1 million microfarads (µF) are equal to 1 farad, this means that to change 80 µF to farads, we divide 80 by 1,000,000. The quotient, or the answer to this problem in long division, is 0.000080. (All you must do to arrive at this answer is to watch your decimal points.) By substituting our equation, we find that

$$X_C = \frac{1}{6.28 \times 60 \times 0.000080}$$

which means $X_C = 33.2$ ohms of capacitive reactance.

Knowing the capacitive reactance and by checking our formula chart, we find that to solve for the current flow in a capacitive-reactance circuit as follows:

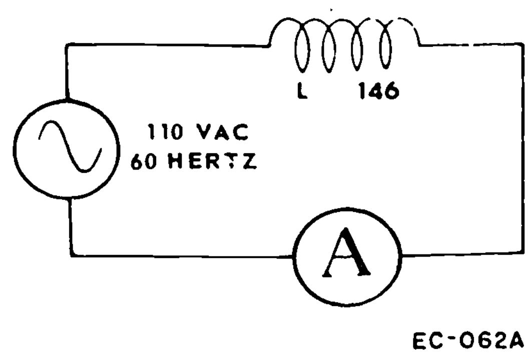



Figure 1–25. Industance in an AC circuit.

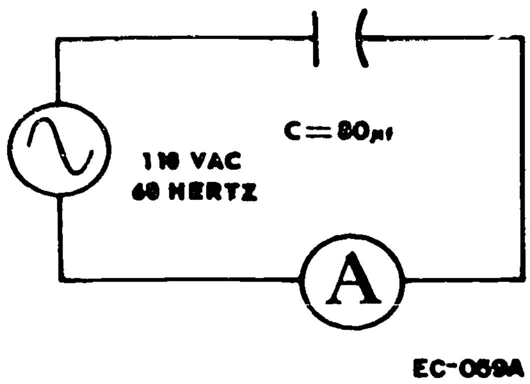



Figure 1-26. Capacitance in an AC circuit.

$$I = \frac{E}{X_C}$$

and, by substitution,

$$I = \frac{110 \text{ volts}}{33.2 \text{ ohms}}$$

Therefore,

$I = 3.31$ amperes

*Reactance and resistance*. The circuit problems used above have been comparatively simple. Now, suppose an AC circuit contains reactance and resistance. Then reactance ($X_L$ or $X_C$) can no longer be simple substituted for the resistance, R, in Ohm's law for computing current flow. We must use the combination of the two factors, which is called impedance, or Z.

Thus, in cases such as these, two entirely new formulas are used to find the opposition to current flow. In an AC circuit containing resistance and inductance, the formula is:

$$Z = \sqrt{R^2 + X_L^2}$$

and, if the circuit contains resistance and capacitance,

$$Z = \sqrt{R^2 + X_C^2}$$

To illustrate our first formula, suppose we draw an AC circuit (fig 1-27) that contains both resistance and inductance. In this circuit, resistance (6 ohms) and inductance (0.021 henry) are connected in series with a 110-volt AC, 60 hertz supply. Our problem is to find the impedance and the current through the lamp and the coil.

Because we already know the resistance, in order to find total impedance, we must first compute the inductive reactance of the coil. Why? Because the impedance is the combined effect, in this case, of resistance and the inductive reactance. So we use our formula for computing inductive reactance,

$$X_L = 2\pi \times f \times L$$

and substitute accordingly:

$$X_L = 6.28 \times 60 \times 0.021$$

therefore,

$X_L = 8$ ohms of inductive reactance

Our next step is to compute the total impedance by using our first formula, including, or course, our known resistance:

$$Z = \sqrt{R^2 + X_L^2}$$

we substitute

$$Z = \sqrt{6^2 + 8^2}$$

therefore,

$$Z = \sqrt{36 + 64}$$

$$Z = \sqrt{100}$$

and, by taking the square root,

$Z = 10$ ohms of impedance

The current flow can now be solved by Ohm's law method,

$$I = \frac{E}{Z}$$

$$I = \frac{110}{10}$$

$I = 11$ amperes

Now, let's find out how much of a voltage drop there is across the resistance in this circuit. After that we'll see how much there is across the inductance.

You learned that when there is a voltage drop in a DC circuit it is equal to the sum of the voltage across each of the resistances, and that the method of solving such a problem is to use the formula taken from the Ohm's law chart for DC circuits, $E = I \times R$.

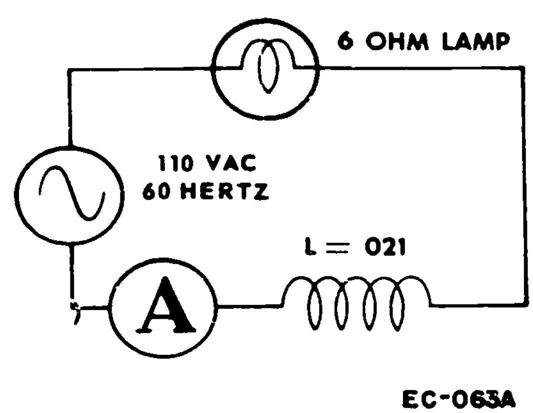



Figure 1-27. Resistance and inductance in an AC circuit.

In an AC circuit, however, $E_R$ represents the voltage drop across the resistance. Therefore, $E_R$ can be substituted for E in the above formula and, as our AC equivalent, we have:

$E_R = I \times R$

$E_R = 11 \times 6$

$E_R = 66$ volts, the voltage drop across the resistance

Because the inductive reactance is opposition, the drop across the inductance is expressed as $E_{X_L}$. Thus, our formula is now:

$E_{X_L} = I \times X_L$

Therefore,

$E_{X_L} = 11 \times 8$

or

$E_{X_L} = 88$ volts, the voltage drop across the inductance

Just a minute! This doesn't look right! Here we have a 66-volt drop across the resistance and an 88-volt drop across the inductance. The sum of these two voltages, by simple addition, is 154 volts -44 volts greater than the impressed voltage! Actually, the reason for this is quite simple. It is merely the result of the two voltages being out of phase.

The mathematical analysis of the circuit shows clearly that in an AC circuit, unlike in DC, the amount of current flow depends not only on the resistance but also on the inductance in the circuit. As a matter of fact, in an AC circuit, inductance can have far more influence on the current flow than does resistance. As you have seen, in this case it has the greater control over the current.

If you will compare our computations here with those relating to DC circuits, it should be plain enough that resistance has the same effects in an AC circuit as it has in a DC circuit. The difference found in the effects of inductance in DC and AC circuits results largely from the fact that AC constantly changes in direction or value. This constant change causes variation in the magnetic fields. The magnetic field is, of course, associated with inductance and any variance in the magnetic field is going to cause a variance in the circuit characteristics.

When there is capacitive reactance as well as resistance in an AC circuit, we use our second formula to find the total impedance:

$$Z = \sqrt{R^2 + X_C^2}$$

To find the capacitive reactance, we use the formula:

$$X_C = \frac{1}{2\pi \times f \times C}$$

In the series circuit, as shown in figure 1-28, there is a capacitor of 200µF connected in series with a 10-ohm lamp. Let's find the total impedance, the amount of current, and the voltage drop across the resistance.

First of all, just as you did in the previous capacitance problem, the µF quantity must be changed back into farads:

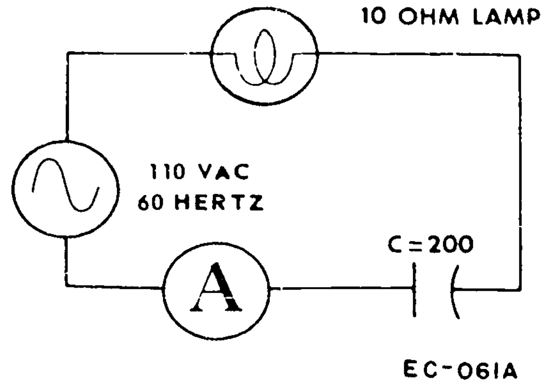



Figure 1-28. Resistance and capacitance in an AC circuit.

$$200 \text{ microfarads} = \frac{200}{1{,}000{,}000} = 0.0002 \text{ farads}$$

Again, since resistance is known, we can substitute in our formula to find the capacitive reactance:

$$X_C = \frac{1}{2\pi \times f \times C}$$

$$X_C = \frac{1}{6.28 \times 60 \times 0.000200}$$

$$X_C = \frac{1}{0.07536}$$

$X_C = 13$ ohms, the capacitive reactance

Then, to find the total impedance, we use the impedance formula for circuits containing capacitive reactance and resistance, which, as you just read, is:

$$Z = \sqrt{R^2 + X_C^2}$$

and, by substituting,

$$Z = \sqrt{10^2 + 13^2}$$

$$Z = \sqrt{100 + 169}$$

$$Z = \sqrt{269}$$

$Z = 16.4$ ohms, the total impedance

To solve for current flow in this circuit, we return to Ohm's law:

$$I = \frac{E}{Z}$$

$$I = \frac{110}{16.4}$$

$I = 6.7$ amperes

and, to find the voltage drop across the lamp,

$E_R = I \times R$

$E_R = 67$ volts

Since the voltage drop across the capacitor is expressed as $E_{X_C}$, therefore,

$E_{X_C} = I \times X_C$

$E_{X_C} = 6.7 \times 13$

$E_{X_C} = 86.1$ volts

As in our circuit containing resistance and inductance, we find that these two voltages do not equal the supposed applied voltage of 110 volts. Here, again, you have a circuit in which E and I are out of phase, but, instead of lagging the voltage, being a capacitive circuit the current is leading the voltage.

In an AC circuit containing more than one Ohmic factor, voltage is expressed as $E_T$. To find the applied voltage in order to prove your computations, you can use the equation:

$$E_T = \sqrt{E_R^2 + E_{X_C}^2}$$

$$E_T = \sqrt{67^2 = 86.1^2}$$

$$E_T = \sqrt{4489 + 7413}$$

$$E_T = \sqrt{11902}$$

$$E_T = 110 \text{ volts}$$

The answer, 110 volts, indicates that the supposition expressed in the previous paragraph was correct.

Now, how about a circuit that contains not only resistance and capacitive reactance, but also inductive reactance? Look at figure 1-29. Since $X_L$ and $X_C$ tend to cancel each other out, they should be expressed as $X_L - X_C$. Therefore, the impedance equation for a circuit containing resistance, inductive reactance, and capacitive reactance is:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{4^2 + (10 - 7)^2}$$

$$Z = \sqrt{4^2 + 3^2}$$

$$Z = \sqrt{16 + 9}$$

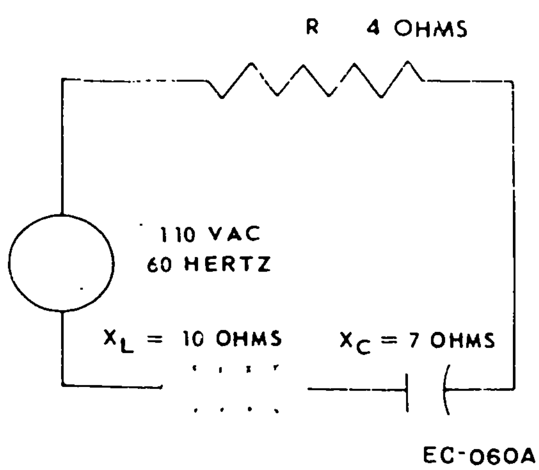



Figure 1–29. Resistance, inductance, capacitance in an AC circuit.

$$Z = \sqrt{25}$$

$$Z = 5 \text{ ohms}$$

As you should have begun to understand, many of the ideas you absorb in your study of DC circuits are applicable to AC circuits. Those features that you have found to be different are caused by the constant changing of the direction and the magnitude of alternating current. The rules and equations for DC circuits apply to AC circuits having resistive load elements alone. This would include load elements such as lamps, resistors, and heating elements; but, when the AC circuit contains reactive load elements, they must be taken into consideration also. The reason for this is that the current through a reactive component is not in phase with the applied voltage. The effect of this out-of-phase condition must be taken into consideration when calculating values in AC circuits. The typical load on an AC power system includes lights, motors, relays, solenoids, heating elements, etc. This provides both resistive and reactive load elements. The amount of inductive reactance far exceeds the amount of capacitive reactance in the typical circuit. Overall, the inductive reactance has a significant influence on the circuit.

**Exercises (209):**

1. What is the difference in current flow between an AC or DC circuit that contains only resistance?

2. Select the correct formula in column B that would be used to solve the statements in column A.

| *Column A* | *Column B* |
|---|---|
| ____ (1) Inductive reactance. | a. $Z = \sqrt{R^2 + X_L^2}$ |
| ____ (2) Circuit containing resistance and inductive reactance. | b. $Z = \sqrt{R^2 + (X_L - X_C)^2}$ |
| ____ (3) Circuit containing resistance, reactance, and impedance. | c. $X_L = 2\pi \times f \times L$ |
| ____ (4) Capacitive reactance. | d. $Z = \sqrt{R^2 + X_C^2}$ |
| ____ (5) Circuit containing resistance, and capacitive reactance. | e. $X_C = \dfrac{1}{2\pi \times f \times C}$ |

**210. State the conditions when true power is less than or equal to apparent power, and give the formula for the power factor.**

**Power in AC Circuits.** We have previously learned that the unit of electrical power is the watt and that electrical

power is the rate at which electrical energy in a circuit is expended. Another way of expressing the same thing is that power is the rate of doing work. In DC electricity, power is equal to the voltage multiplied by the current in the circuit. For obtaining the power in a DC circuit, the formula reads P = EI, or watts equals volts times amperes. Consequently, if 1 ampere flows in a DC circuit with a pressure of 220 watts behind it, the power is 220 watts. This product of the volts and the amperes is what is known as the true power in the circuit. In the previous section we were talking about DC circuits and here we are discussing AC. Actually, they are similar. However, in an AC circuit a voltmeter indicates the effective voltage and an ammeter indicates the effective current. Apparent power is the product of these two readings. It is only when the AC circuit consists of pure resistance that the apparent power is equal to the true power.

The ratio between the apparent power and the true power is known as the power factor. It is usually expressed in percent and the formula is written:

$$\text{Power factor} = \frac{\text{true power}}{\text{apparent power.}}$$

The reason for the equation being written in this fashion is that the difference between true power and apparent power is directly caused by the phase separation of the voltage and current in an AC circuit. It seems logical to expect a very definite relationship between the phase angle, the true power, and the apparent power. To find the phase angle, which is illustrated by figure 1-30, we must divide the true power by the apparent power—the apparent power (volt-amperes) being the power delivered (watts) to the circuit, the true power (or effective power) being the power actually consumed by the circuit.

Let's take a look at the power relations in an AC circuit. In figure 1-31, note the triangle that displays the relationship between reactive power, true power in watts, and apparent power, volts times amperes. If the circuit were a pure resistance circuit and contained no reactance, the reactive power leg of the triangle would diminish to zero. Apparent power and true power would then lie along the same line and would be equal.

In an AC circuit, the true power is less than the apparent power when the current and voltage are out of phase. This out-of-phase condition is caused by the amount of capacitance or inductance (reactive power) in the circuit. The true power in an AC circuit must, therefore, be obtained by a wattmeter reading and not by multiplication as it is in DC circuits. It is the ratio of the true power (base line) to the apparent power (hypotenuse) that is called the power factor, usually expressed in percent. Let's look at this relationship in equation form:

$$\text{Power factor} = \frac{100 \times \text{watts (the true power)}}{\text{volts} \times \text{amperes (the apparent power)}}$$

Because we cannot compute the true power in an AC circuit, figure 1-32 should clarify the measurement of the power factor in a typical circuit. As you can see, the 220-volt AC motor is apparently taking 50 amperes from the line. The wattmeter in the line, however, shows that only 9350 watts are taken by the motor. Obviously there is a disparity here and we've got to go a little further. We have to find the apparent power and the power factor to analyze the situation. In a case like this, we use our equation. We know that the apparent power is equal to the volts times the amperes,

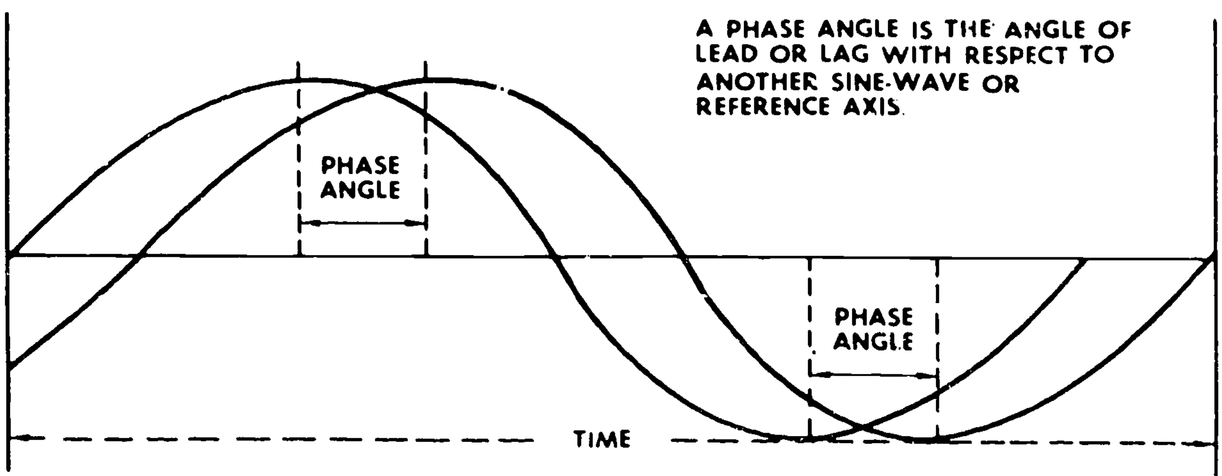
Apparent power = 220 × 50 or 11,000 volt-amperes

Therefore,

$$\text{Power factor} = \frac{9350 \times 100}{11{,}000}$$

$$\text{pf} = \frac{935{,}000}{11{,}000}$$

pf = 85, or 85 percent




ED-009

Figure 1-30. Phase angle.

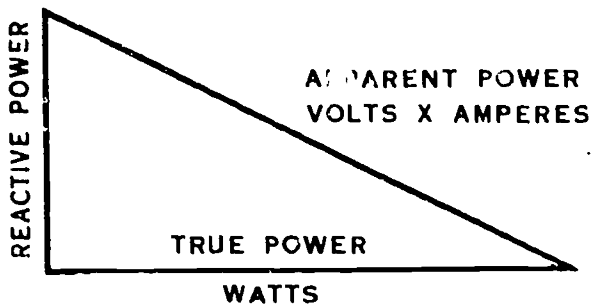


Figure 1–31. Power relationship.

As pointed out earlier, volt-amperes in alternating current is important because it determines the operating limits of an AC generator. Since it is important, perhaps a further word should be said in regard to these operating limits.

The output limits of an AC generator are determined chiefly by the temperature rise that is produced in the windings. This increase in temperature is caused by core and copper losses. Core losses depend on the frequency and the flux density and are fixed by the operating voltage and frequency; these, you can do nothing about. Copper losses, on the other hand, are determined by the amount of current, and this you can control. Full load (maximum output capability) is reached when the generating equipment is carrying the full rated current at the rated voltage and frequency. Any increase in load that exceeds the rated output will likely cause overheating and probable damage to the generator.

**Wattless Power—VARs.** We have discussed power as it relates to the DC circuit and asserted that the heating effect of electrical current is electrical power at work and the unit of electrical power is the watt. We also stated that electrical power is the time rate at which electrical energy is expended in a circuit. Now we must consider that while in AC, as in DC, we have the watt as a unit of power, we also have another type of power called wattless power, which is expressed in VARs, or the volt-amperes reactive.

The presence of either capacitive reactance or inductive reactance, as you have learned, will cause the circuit current and voltage to be separated by some phase angle between 0° and 90°. But, and remember this, it will always be less than 90° because all circuits contain some resistance to current flow, and resistance has the effect of moving current and voltage back towards an in-phase condition.

The power that is the result of applied voltage, and that particular element of current that is in phase with it, is the actual power dissipated in the circuit. You should note, however, that not all applied power dissipated by an electrical device is delivered in the form of useful power. Some of the applied energy is lost in heat, expressed as $I^2R$, caused by the current being dissipated in the resistance of the circuit. The $I^2R$ loss represents a direct conversion of electrical energy into heat energy in the resistance.

That part of the current not transformed into heat is, in this manner, 90° out of phase with the applied voltage. It is this out-of-phase current that produces the magnetic field in inductive devices such as coils. This portion of the applied power that produces the magnetic field is known as wattless

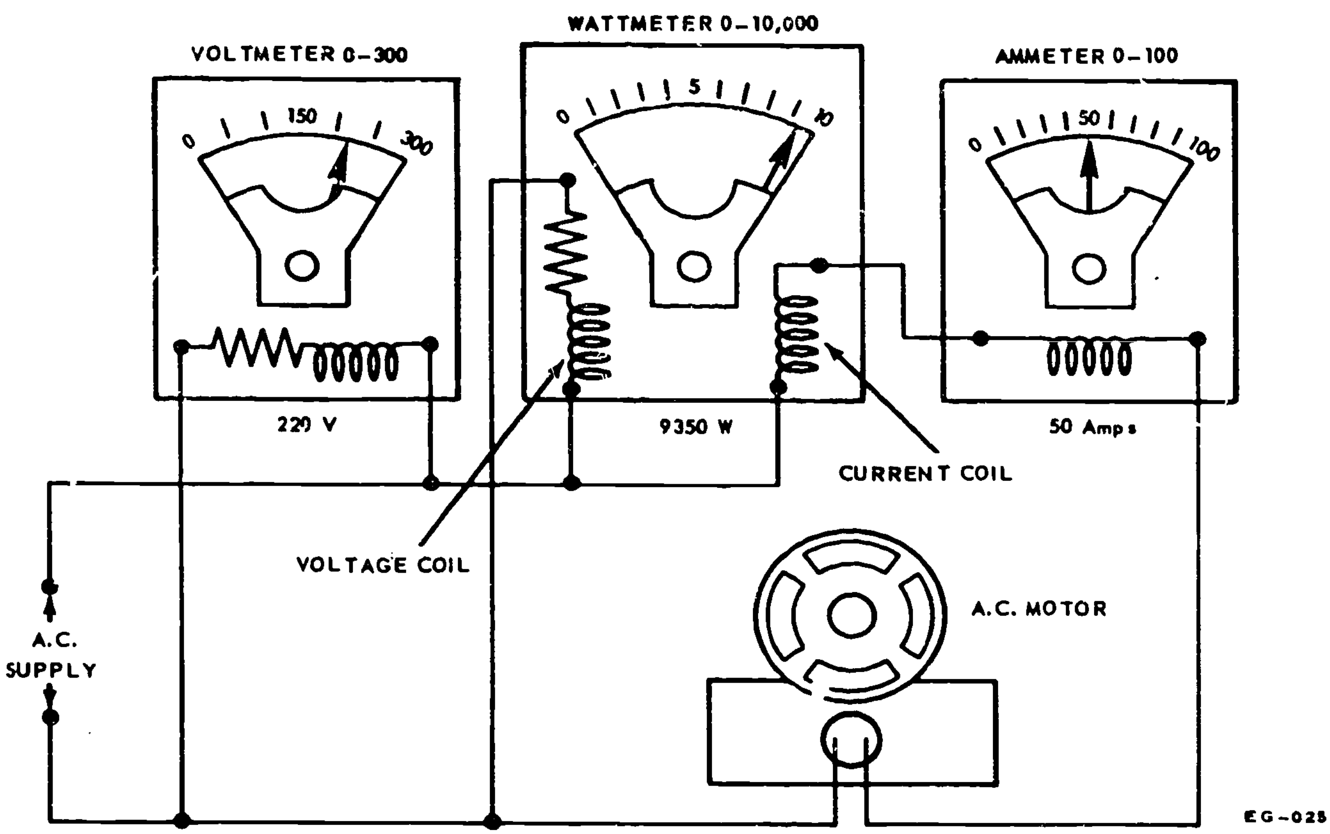


Figure 1–32. Measurement of the power factory.

power, or reactive power, and is expressed in VARs. Actually, it is not power at all because it consumes no energy, since all the energy stored in magnetic or electrostatic fields is returned to the source of power when the fields collapse. Since none of this energy is converted into kinetic energy, except those $I^2R$ losses associated with the induced current flow through resistances, there is no consumption of power. For this reason, VARs or volt-amperes reactive are spoken of as wattless power.

**Exercises (210):**

1. When, in an AC circuit, is the apparent power equal to the true power?

2. When is the true power less than the apparent power?

3. What is the formula for power factor?

4. A 240 volt AC motor records 35 in-line amperes. The in-line wattmeter shows only 7600 watts being consumed. What is the power factor of the AC circuit?

5. What is the portion of the applied power that produces the magnetic field in an AC circuit called?

## 1-4. Basic Electrical Power Sources

Now we will discuss the sources of voltage. To produce voltage, some form of energy must be used to bring about the action of electrons. The six basic sources of energy that can be used are friction, pressure, heat, light, magnetism, and chemical action. Although all of these sources of energy provide some practical sources of power, our discussion will be limited to two of the six. The two that supply the majority of our power are magnetism and chemical action. The first to be covered is a power supply that makes use of magnetic energy.

### 211. Specify the function of elementary generators and alternators.

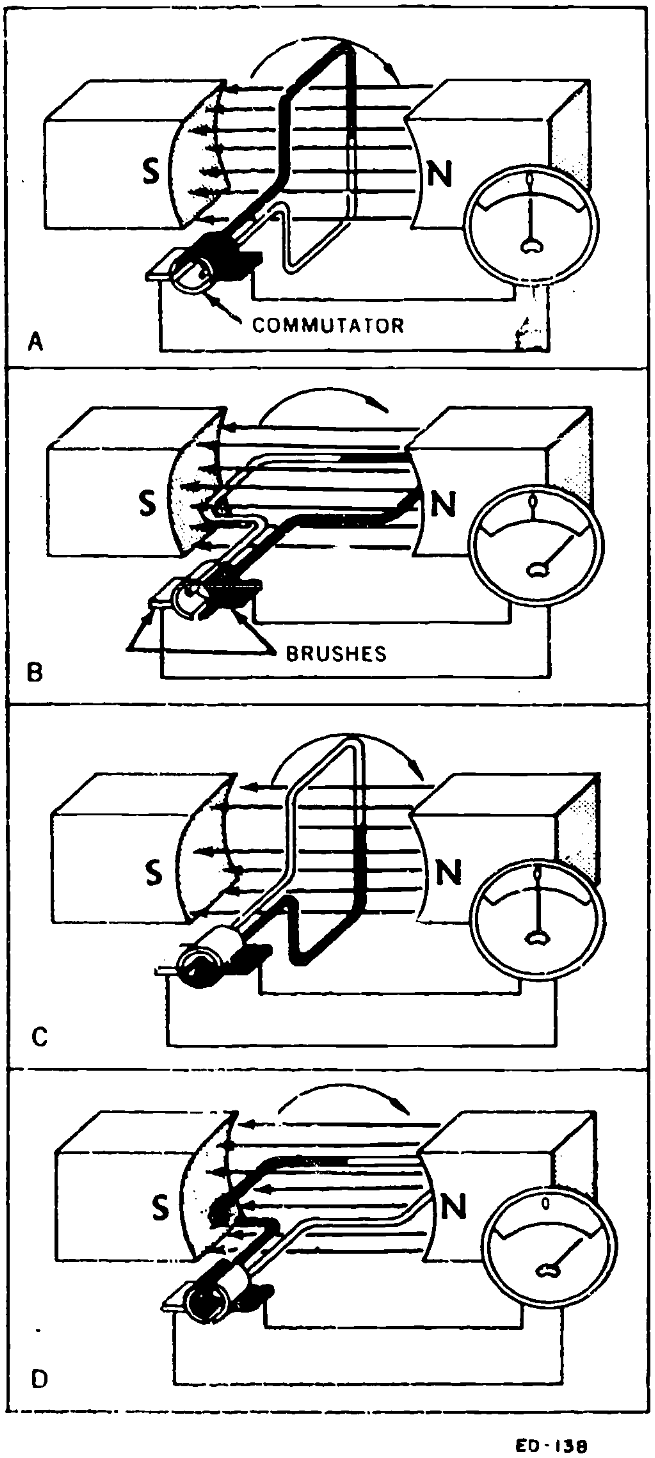
A generator is a machine that converts mechanical energy into electrical energy. The machinery that supplies mechanical energy to the generator is usually called the prime mover. There are many types of prime movers—water power and diesel or gasoline engines, for example. The electrical power (electromotive force) output from a generator may be either direct current or alternating current, depending upon the construction. However, in principle, the rotating coils and the magnetic field through which they turn are the same for both types of generators. The primary difference between AC and DC generators is the method by which the current is taken from the machine.

Elementary DC Generator. An elementary DC generator can produce voltage with a rotating loop of wire in a magnetic field. In a generator, we have two sets of coils and a field; one set of coils is in motion and the other set of coils acts as an electromagnet around the pole pieces to set up a magnetic field. A simplified diagram of a DC generator is illustrated in figure 1-33. A loop of wire represents the conductor which rotates in the magnetic field. The ends of the loop terminate in two copper half rings that are insulated from each other. Fixed brushes make contact with the copper rings to conduct electricity to the external circuit. The loop is rotated in a clockwise direction. In position A, the conductors of the loop are moving parallel with the field; and since the conductor is not cutting the lines of force there is no voltage.

At position B, the loop is moving at right angles to the field and voltage is at a maximum. At position C, the loop is again moving parallel with the field and voltage is zero. At position D, the loop is cutting across the field and voltage is again at a maximum. Notice that the sides of the loop have now reversed themselves, but voltage to the external circuit (the galvanometer) is still in the same direction. As the brushes are stationary, they deliver direct current because either conductor in contact with a particular brushes will have the same direction of motion across the field. Check the black brush in figure 1-33 at positions B and D, and you will see that the sides of the loop change but the brushes remain stationary. With two brushes riding on the commutator to carry the current on an external circuit, you will have an elementary DC generator producing direct current.

**Elementary AC Generator.** A simplified diagram of an AC generator is shown in figure 1-34. The difference between the DC generator and the AC generator is in the method used to deliver the current to the brushes. In the AC generator, sliprings are used instead of a commutator. This means that the same side of the loop delivers current to the same brush regardless of rotation; otherwise, the operation is the same. Figure 1-34 shows the loop turning in a clockwise direction.

At position A, the conductors are moving parallel to the field; therefore, no voltage is produced. At position B, the conductors are cutting across the field and the galvanometer indicates the direction of current by the needle pointing to the right. At position C, the meter shows zero as the conductors are again moving parallel with the field. At position D, the conductors are again cutting the field and the meter shows maximum voltage but in the opposite direction. What happened? At position B, the black side of the loop is moving up through the field. Now the black slipring is negative. Current is directed from the white slipring to the meter and back. The direction of current in the loop reversed itself and the same is true in the external circuit to the meter.



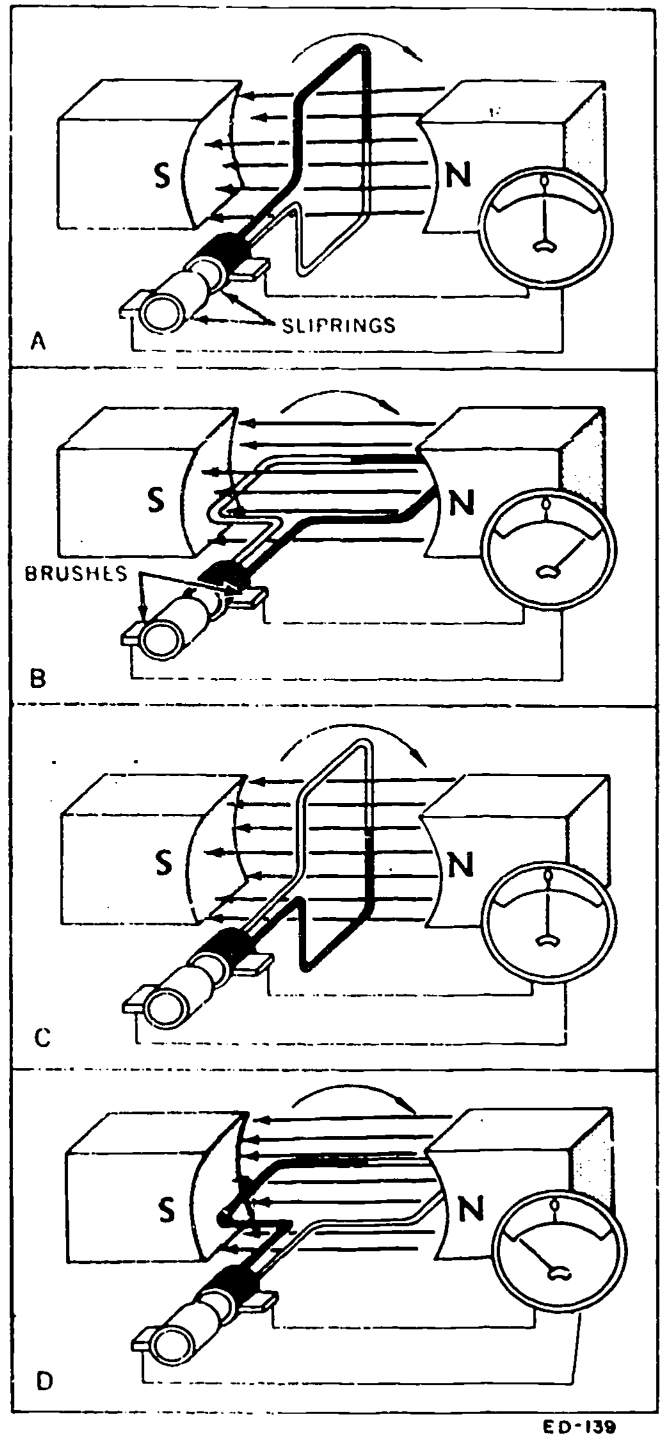




Figure 1-34. Simplified diagram of an alternating-current generator.

Figure 1-33. Simplified diagram of a direct-current generator.

The two ends of the loop are connected to sliprings. Two brushes ride on the sliprings. By rotating the loop, a current is generated. The current, in turn, is transferred by the brushes to an external circuit. You now have an elementary AC generator.

An AC generator and a DC generator, then, are identical in generating voltage by use of the rotating loop. If the current is taken from the loop by sliprings, it is an alternating current and the generator is called an AC generator. If the current is collected from a commutator, it is direct current and the generator is called a DC generator. You will find that AC generators are normally referred to as alternators.

Exercises (211):

1. What is the function of a generator?

2. Check the following correct statements concerning generators and alternators.

___a. Any DC generator must have a commutator.
___b. There is a difference between the rotating coils and the magnetic field of an AC and DC generator.
___c. If current is taken from a rotating loop by sliprings, then it is alternating current.
___d. The difference between AC and DC generators is the method of collecting the current.
___e. When the generator rotating loop is parallel with the field, it will be producing maximum voltage.
___f. A generator takes the energy of the prime mover and changes the energy to electrical power.

**212. Identify types of alternators, and state the operation of single- and three-phase output.**

**Alternators.** Almost all of the alternators used in electrical power production by the Air Force are of the synchronous type with rotating fields and stationary armatures. With this type of construction, the fields are wound on rotor poles and the armature coils are assembled inside the alternator frame to form a stator assembly.

*Types of alternators.* Generally speaking, alternators are of two types—single-phase and three-phase. They all look alike but are constructed differently. Thy operate on the principle of either moving conductors across a magnetic field or moving a magnetic field across the conductors. In either case, the results are the same. However, most of the AC alternators used in electrical power production are designed so that the magnetic field is moved across the conductors. With this construction, the AC output is taken directly from the stationary stator coils. Thus, no brushes or sliprings are used in the alternator high voltage output, but they are used to feed relatively low DC to the rotor coils to produce the magnetic fields.

*Single-phase alternator.* A single-phase alternator is the simplest type. Notice the schematic wiring diagram of the single-phase alternator in figure 1-35. As shown by the sine wave in the diagram, the rotor revolves through one full revolution and produces one cycle of alternating current. The first half revolution of the rotor produces a voltage in one direction and completes the first half of the cycle; the second half revolution produces a voltage in the opposite direction and completes the last half of the cycle. This alternator will produce only one cycle of AC voltage during one revolution of the rotor. Since there are no overlapping cycles produced by the alternator, the voltage output is only single-phase.

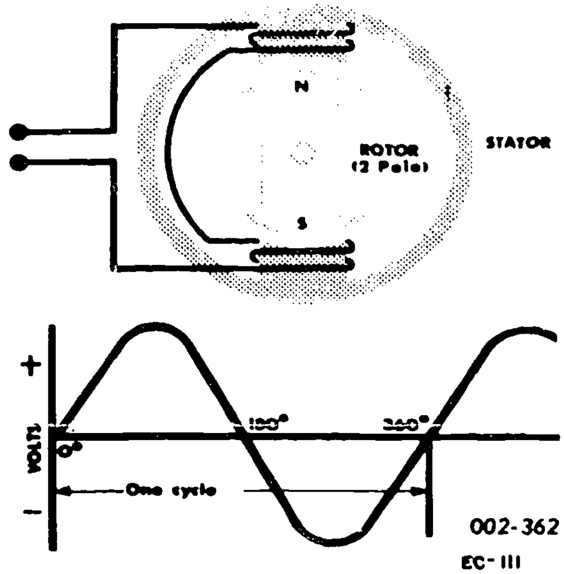



Figure 1-35. Schematic of a single-phase alternator.

*Three-phase alternator.* The output of the three-phase alternator can be used to operate virtually all electrical equipment at any Titan missile launch complex. For this reason, the three-phase alternator is most commonly used in electrical power production. While the output of this alternator is being used to operate three-phase equipment, any one of its phases can be used simultaneously to operate single-phase equipment.

Figure 1-36, a wiring diagram of the three-phase alternator shows the stator fields connected in pairs to produce a three-phase output. As the rotor turns through one revolution each phase produces one cycle. By overlapping the cycles, as shown by the sine wave, the three-phase alternator produces a three-phase voltage output.

In actual construction, the rotor pole windings of an AC alternator are electromagnets whose magnetic strength is controlled by the amount of DC voltage applied to the brushes and sliprings. An increase in DC voltage applied to the brushes and sliprings causes an increase in current through the rotor pole windings. This increase in current produces a stronger magnetic field and provides a greater AC output. On the other hand, when less DC voltage is applied to the rotor pole windings, the alternator will have a lower AC output.

To furnish electric current for exciting the rotor pole windings of an alternator, a source of direct current must be provided. This current is produced by an exciter. The

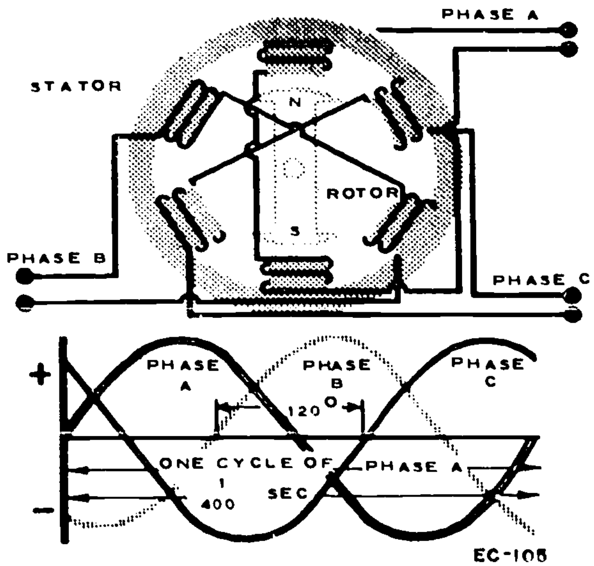



Figure 1–36. Schematic of a three-phase alternator.

exciter is a simple, direct current generator with a rotating armature and stationary field coils. The basic components of the exciter are the same as those for a generator.

As the rotor of a three-phase alternator revolves, each phase delivers voltage in a given sequence according to the method in which the alternator is connected. These phase voltages occur 120 electrical degrees apart. That is, when a cycle is started in a given direction by phase one, either phase two or phase three must start a cycle in the same direction 120 electrical degrees later. Also, a third cycle must be started in the same direction 120 electrical degrees after the start of the second cycle. The order in which these cycles are generated is called phase rotation.

***Alternator Output Connections.*** You will find that there are two methods of connecting three-phase alternators. These are the DELTA and WYE methods.

*Delta connection.* With the delta connection, the three alternator phases are connected together as you see in figure 1-37. In this illustration, each coil of the delta represents one phase of the alternator. The voltage between any two lines is the same as the voltage of the coil between the lines (phase voltage). For example, if 2400 volts were generated in each phase of the alternator, the voltage between any pair of the three lines would also be 2400 volts.

*Wye connection.* With the wye-connected alternator, the phases are connected as shown in figure 1-38. In this type connection, the voltage between any phase line and neutral is equal to alternator phase voltage—2400 volts in this illustration. The voltage between any two of these phase lines, however, is approximately 4160 volts.

**Exercises (212):**

1. What are the types of alternators?

2. What are the two ways that an alternator might operate?

3. By what methods might a three-phase alternator be connected?

4. What are the operations of a single-phase alternator?

5. What is used to supply the DC voltage in a three-phase alternator for the magnetic field?

6. How many degrees are the poles set apart for three-phase operations of an alternator?

**213. Distinguish between primary and secondary cells, and specify how storage batteries are constructed.**

**Batteries.** A battery is a device used to produce a voltage by chemical means. When such a source of voltage is connected to a closed circuit, chemical energy is changed to electrical energy. Other than generators, chemical action is the most common source of electrical energy. Today, most of us use batteries in some way. We start our cars and play our portable radios with the energy from a battery. We use batteries for emergency light and power, for alarm circuits, and for the operation of relays and other devices.

A true battery is made up of units called cells. The terms "cell" and "battery" are often used interchangeably. All cells are divided into two general types—primary and secondary. Once the primary cell is used up it is useless. On the other hand, the secondary cell may be recharged. In

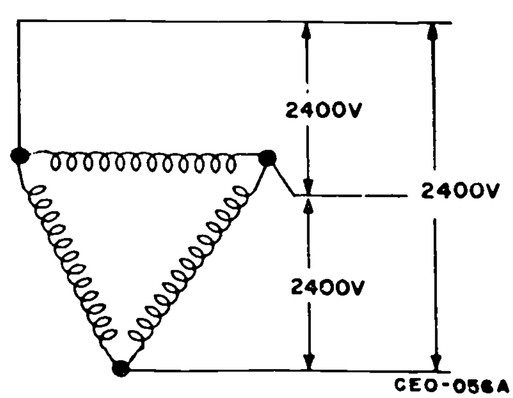



Figure 1–37. Delta connection.

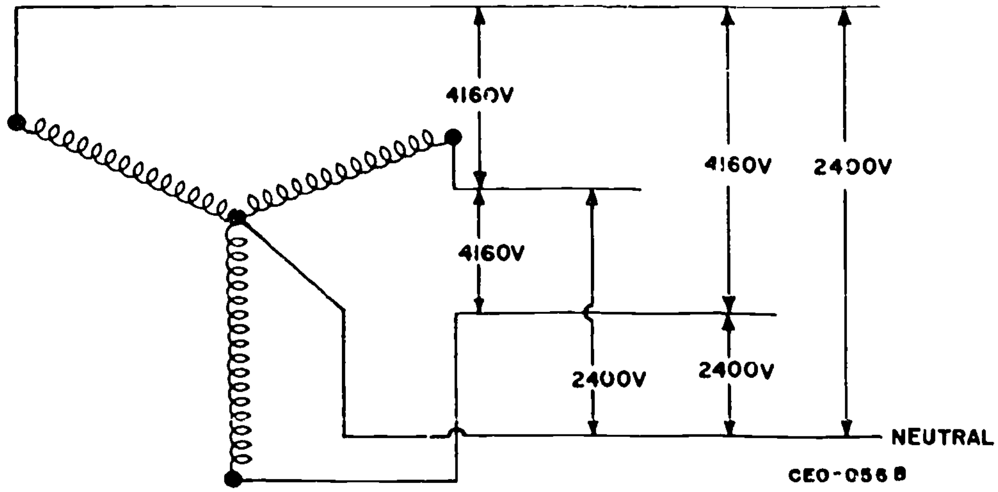



Figure 1–38. Wye connection.

the following paragraphs we discuss the primary cell and the storage battery. The storage battery consists of two or more secondary cells.

***The primary cell.*** There are many sizes and shapes of primary cells in use today and to try to cover them all would take a book in itself. The most common primary cell is the dry cell, the type used in an ordinary flashlight. A cross-sectional view of a dry cell is shown in figure 1-39. The two terminals are connected to plates in the cell and are called electrodes. The zinc can serve as the negative electrode, as well as the container for the cell; the carbon rod serves as the positive electrode. The electrolyte consists of a chemical dissolved in water and mixed with a thick paste.

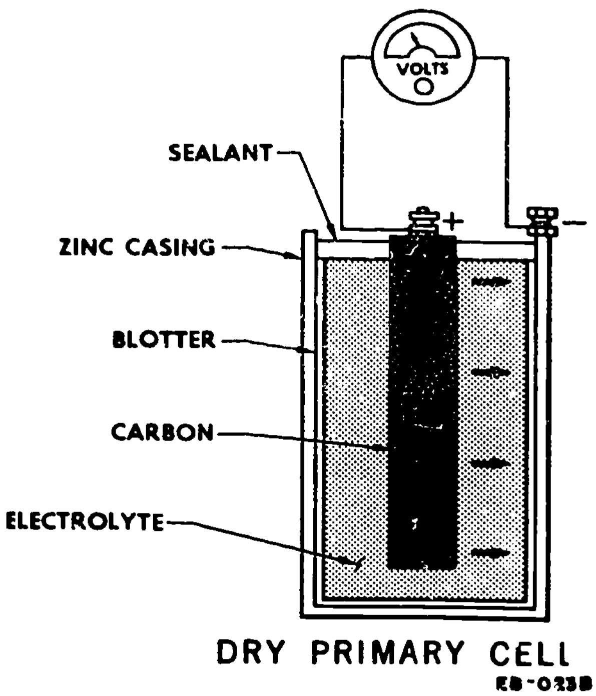



Figure 1–39. Primary (dry) cell.

The paste prevents the electrolyte from spilling. The top of the cell is sealed to prevent evaporation of moisture and to keep the contents of the can from spilling. Connections to the cell are made by means of the terminal posts which are connected to the zinc and carbon electrodes.

When the cell is connected to a circuit, a chemical reaction takes place between the electrolyte and the negative electrodes. This reaction results in a current flow from the negative terminal through the external circuit and back to the positive terminal.

A single primary cell of the type shown in figure 1-39 develops a voltage of 1.5 volts. Keep in mind that the size of the cell has nothing to do with the voltage that it can develop. The voltage depends on two factors only—the type of electrolyte and the electrode material. The amount of current that a cell can furnish, however, is dependent upon the area of the plates exposed to the electrolyte, or the amount of current is directly dependent on the cell size. This is why flashlight batteries are quite small, whereas batteries designed for heavier current flow are much larger.

We said that the voltage developed by a primary cell is 1.5 volts. This is the open circuit or no-load voltage. When a cell is supplying current to a circuit, the voltage is somewhat lower. The voltage under a load is called terminal voltage.

*The storage battery.* The most common storage battery is the lead-acid type, so called because the plates are made of lead and the electrolyte is acid. Probably the type of storage battery with which you are most familiar is the type used in cars and trucks (see fig. 1-40).

In a previous paragraph, we defined a battery as being made up of two or more cells. The exact number of cells, of course, depends on the desired voltage. Most cars, for example, use a 12-volt, lead-acid battery. The battery consists of six cells (2 volts each) connected in series.

The battery is contained in a case that is divided into compartments; one compartment for each cell. Groups of positive and negative plates are assembled to form an element and each element makes up one cell. The elements are immersed in a sulfuric acid and water solution called

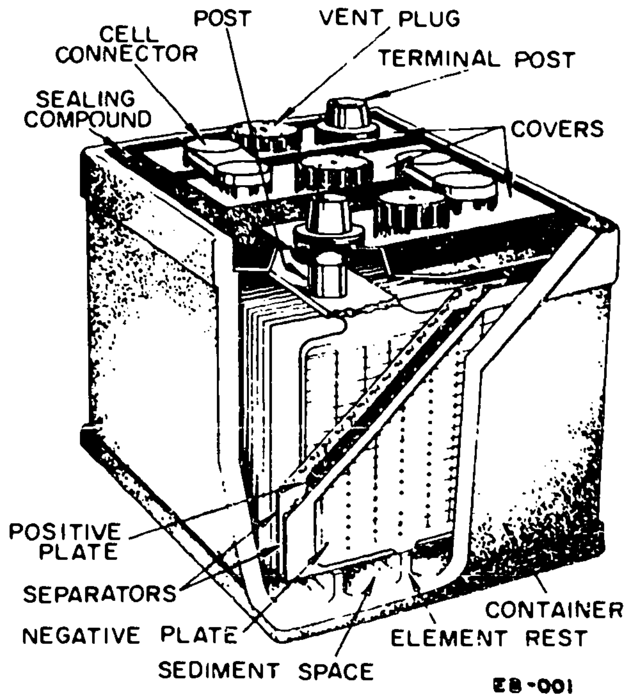



Figure 1-40. Lead-acid battery.

electrolyte. Thin sheets of wood, porous rubber, or glass fiber (called separators) are placed between the plates to prevent them from touching and causing a short circuit.

The battery plates are made in the form of a grid which is filled with a soft lead paste, the active material in the plates. Several plates are put together to form a positive group and a negative group. The plates of each group are connected together and then connected to the external terminal or connecting post.

When a lead-acid type battery is charged and in operating condition, the active material on the positive plates is lead peroxide, and on the negative plates it is spongy lead. When the battery is discharging, the plates undergo a chemical change. The acid from the electrolyte unites with the active plate material, and lead sulfate is formed on both the positive and the negative plates. During discharge, the acid content of the electrolyte is decreased. If the battery is allowed to continue discharging, the sulfate deposit on the plates increases until no further chemical action can take place. In this condition, the battery is said to be completely discharged. Under normal operating conditions the battery is not allowed to become completely discharged. A battery in which the plates have been allowed to accumulate a heavy deposit of lead sulfate is practically useless because it is almost impossible to recharge a battery in this condition.

The voltage of a battery is determined by the number of cells that it has connected in series. Although the open-circuit voltage of a lead-acid cell is approximately 2.2 volts, the cell is normally rated at only 2 volts because it drops to that value under load. A battery rated at 12 volts consists of 6 lead-acid cells connected in series, while a battery rated at 24 volts has 12 cells.

Another type of storage battery used in the Air Force is the nickel-cadmium (see fig. 1-41). Its name comes from the composition of the plates—nickel in the positive plate and cadmium in the negative plate. Each cell of this battery is housed in a rubber case protected by a steel can. A special hydrometer is used to check the level of distilled water that is added to the cells to replace water lost by evaporation. Unlike the lead-acid battery, the nickel-cadmium battery contains an electrolyte solution of potassium hydroxide and distilled water. This electrolyte has no charge because it acts as a carrier of ions. For this reason, standard hydrometer readings are of no value in determining the state of charge in a nickel-cadmium battery.

Nickel-cadmium storage batteries have several major advantages over other types of storage batteries. These batteries will recharge by the constant potential method with high initial current loads and will maintain a relatively steady voltage when being discharged at a high current flow. It is possible for these batteries to stand idle in any state for a long period of time without damage. They can withstand extremely cold temperatures and are not subject to failure by vibration or severe jolting. Installation and maintenance of battery banks and chargers will be covered in detail later in this course.

**Exercises (213):**

1. What is the difference between a primary and a secondary cell?

2. When fully charged, what materials make up the negative and positive plates of a lead-acid battery?

3. What solution is used for the electrolyte in a lead-acid battery?

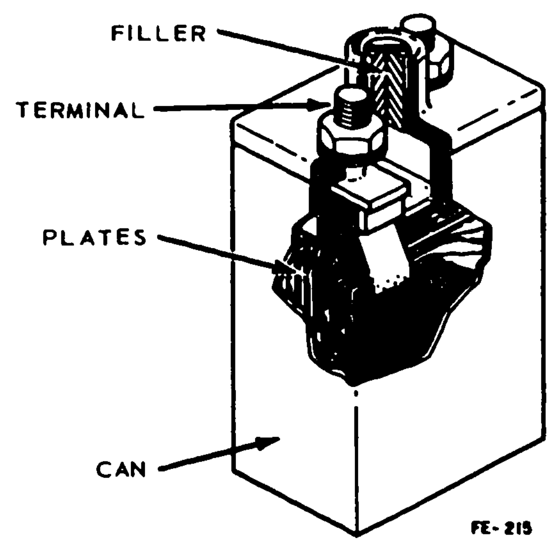



Figure 1-41. Nickel-cadmium battery.

4. What solution is used for the electrolyte in a nickel-cadmium battery?

## 1-5. Transformer Theory and Application

In the discussion of electromagnetism and production of electromotive force, you found out that the induction of a voltage requires a relative motion between a magnetic field and a conductor, and that the motion is produced mechanically in generators and alternators. We can also produce this relative motion electrically by building up and collapsing a magnetic field.

**214. Given pertinent information, determine the output from the secondary winding of a transformer, specify the transformer action that induces voltage, and name the main parts of a transformer.**

**Transformers.** A transformer is a device with no moving parts. It transfers energy from one circuit to another by electromagnetic induction. The energy is always transferred without a change in frequency. The change is usually in voltage and current.

Transformers are built in various shapes and sizes and serve various purposes. A step-up transformer receives electrical energy at one voltage and delivers it at a higher voltage. A step-down transformer receives energy at one voltage and delivers it at a lower voltage. Transformers require little care and maintenance because of their simple, rugged, and durable construction. The high efficiency of transformers is responsible for the extensive use of alternating current.

Various types of small transformers are used in a switchgear. In many installations, transformers are used on switchboards to step down the voltage for indicating lights, instruments, and electrical protective devices. Other common uses include low-voltage supplies for lighting circuits, etc.

Instrument transformers include both voltage and current transformers. They are commonly used with AC instruments to measure high voltages or large currents and to isolate the high-power circuits.

Electronic circuits and devices use many types of transformers to provide necessary voltages for proper operation of components. The physical construction of these transformers differs widely and is not pertinent here.

*Transformer action.* If you apply an alternating current to an electromagnet, a magnetic field will build up and collapse during each half cycle. In other words, the magnetic field that the current builds up during one-half of the cycle will collapse and build up in the opposite direction during the next half of the cycle. For example, a 60-cycle current will build up and collapse a magnetic field 120 times per second. If a second winding is placed around the iron core, the same magnetic field will build up and collapse across the turns on the second winding and induce a voltage in this second circuit. This action is called transformer action and is the principle upon which transformers operate. In actual construction, the iron core of a transformer has two windings (see fig. 1-42): the input, or primary winding, and the output, or secondary winding. If both windings have the same number of turns, the voltage and current induced in the secondary winding are the same as that applied to the primary winding. If the secondary has more turns than the primary, a greater voltage and a smaller amount of current is induced in the secondary than that applied to the primary. If the secondary has fewer turns than the primary, a lesser voltage and a greater amount of current is induced.

*Transformer ratio.* The ratio between the number of turns in the primary to the number of turns in the secondary determines the voltage ratio of the transformer. Figure 1-42 illustrates the relationship between the turns ratio and the voltage. If the left-hand coil is connected to a 110-volt AC source, it would be the primary winding. The turns ratio would be stated as 1 to 2, the primary number being given first because there are twice as many voltage turns (22) in the secondary as in the primary. The voltage induced in the secondary (220) is twice the voltage applied to the primary. A transformer with a greater secondary voltage is called a step-up transformer. If, in figure 1-42, we applied 220 volts to the 22-turn winding, the output of the secondary (11 turns) would be 110 volts. This would be called a step-down transformer because the secondary voltage would be less than the primary. The ratio of the transformer when connected in this way is stated as 2 to 1.

*Transformer taps and ratings.* Transformers are often wound with the secondary split into two coils so that two voltages are available. A 240-volt secondary that has a lead brought out from a center tap will give 120 volts between the center tap and either end of the coil, whereas the full winding produces 240 volts. Taps are also used for voltage regulation in power distribution transformers. A series of taps are brought out, and by changing the tap connection, the voltage is changed. Distribution transformers are usually tapped for a 10-percent change in steps of 2.5 percent. Transformer windings are insulated for the voltage rating stamped on the nameplate. They may be used on lower voltages, but should not be used on higher voltages because the insulation would break down.

A transformer will always have a small current in the primary winding when it is connected to a power source. This is the current necessary to set up the magnetic field in

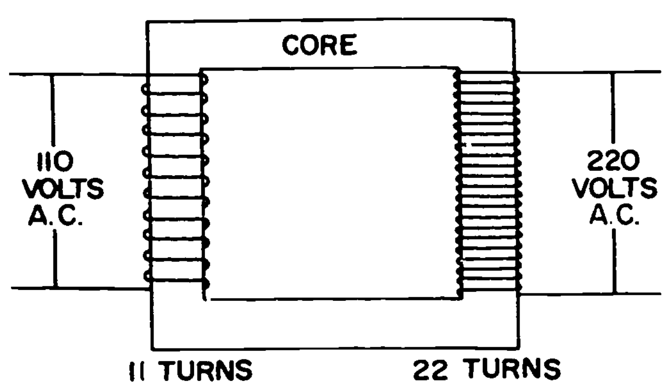



Figure 1-42. Basic transformer.

the core, the charging or magnetizing current. The power rating of a transformer is given on the nameplate. This is the safe loading rating of the transformer and should not be exceeded. You should remember that the transformer is changing electrical power from one voltage value to another. The greatest advantage in transformer use is to transmit power over considerable distances at a high voltage and then to step it down to the desired usable value at the point of use.

*Points to remember*. The following points will help explain to you the theory of the transformer operation:

*a*. A transformer is an AC device that has a primary winding, a secondary winding, and an iron core.

*b*. The primary and secondary are insulated from each other but are linked by the action of the magnetic field, which produces mutual induction.

*c*. The number of turns in the windings determines the turns ratio of the transformer and the ratio between the primary and the secondary voltages.

*d*. A step-up transformer produces a secondary voltage that is higher than the primary voltage. Secondary current is less than the primary current.

*e*. A step-down transformer produces a secondary voltage lower than the primary. Here the secondary current is greater than the primary current.

*f*. The secondary winding may be center-tapped to produce more than one voltage.

*g*. The transformer is one of the most efficient electrical devices in use; it loses very little power.

**Exercises (214):**

1. If the ratio of a transformer is 6 to 1 and the applied voltage to the primary is 120 VAC, what is the voltage output from the secondary?

2. What isolates instruments from high voltages or large currents?

3. What will the transformer with a 1-to-2 turn ratio do to the voltage?

4. What causes voltage to be induced in the magnetic field?

5. Name the main parts of a transformer.

6. What can you do to the secondary winding of a transformer to produce more than one voltage?

## 1-6. Solid-State Devices

Solid-state devices have revolutionized the electronics industry and are being applied in control devices throughout the field. An in-depth coverage of these devices will not be presented in this text since many volumes can be written on theory and application of these components; however, we will discuss how they are applied in control circuitry.

### 215. Specify transistor operation in an electrical circuit.

**Transistors.** Transistors have extremely long life and contribute immensely to the dependability and maximum life of electronic circuitry and components. A transistor is a rugged component that will withstand vibration stress and shock. It uses very little current and is small in physical size for the job it does. Its major disadvantage is its sensitivity to heat and changes in temperature. The transistor is a three-element device made up of semiconductor materials. They are manufactured by several methods. The most popular method is by growing a crystal.

A transistor functions like a vacuum tube in a circuit in that it conducts current in one direction more easily than in the other direction. A transistor also has a third element that acts like an electron gate or switch, which allows more or fewer electrons to flow in the conducting direction. Transistors are made in two basic types. A transistor may be a P–N–P or an N–P–N–type. Figure 1-43 shows the leads and electronic symbols for the two types. Each transistor has an emitter, a base, and a collector. After the transistor crystals are formed and the leads are attached, the entire assembly is placed in a metal enclosure, as shown in figure 1-44.

The materials used as the emitter and collector in a transistor are normally the same size. The material used as the base is usually much smaller than that of the emitter and collector.

Leads are connected to the three different parts of the transistor: the emitter, base, and collector. Of course, it is important to know which lead is connected to which part so that the transistor can be connected in the circuit correctly. There are several different methods you can use to distinguish the difference between the emitter, base, and collector leads on an actual transistor. One of these is the spacing of leads. In certain transistors there will be a large space between two of the leads, and the other two leads will be close together. The center lead will always be the base lead. The lead closest to the base lead is the emitter lead. The remaining lead is the collector lead. This method is shown in figure 1-44,A.

Another method is to mark the collector lead with a red dot, as shown in figure 1-44,B. The red dot indicates the collector lead. The lead farthest away from the collector lead is the emitter lead. The middle lead is the base lead.

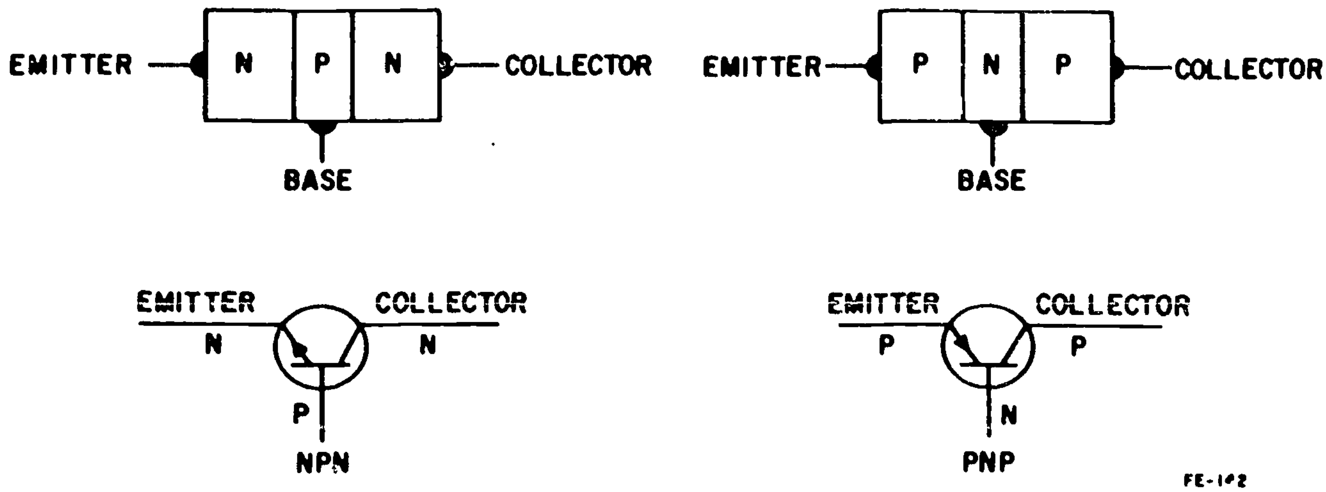



Figure 1–43. Types and symbols of transistors.

The third method is by using numbers 1, 2, and 3. Lead 1 is the collector lead, lead 2 is the base lead, and lead 3 is the emitter lead. Figure 1-45 shows this method.

With a direct current of the correct polarity, positive on the emitter and negative connected to the collector, current can be made to flow through the transistor if a negative signal is applied to the base of the transistor. This signal must be applied between the base and the emitter. This current is known as base current. The transistor will conduct current from the emitter to the collector in proportion to the base current flowing from the emitter to the base. The stronger this base current, the more current flow through the emitter collector circuit. The action is exactly the same as a spring-return water valve; the harder the handle (base) is pushed, the more water (collector current) flow.

Relatively small base currents (microamperes) and voltages (1 volt is typical) cause relatively large (several milliamperes) currents to flow in the collector circuit.

The three-element transistors we have discussed can be connected into three basic types of circuits, as shown in figure 1-46. These are the common base, common emitter, and common collector circuits. In the common base circuit, as shown in A of figure 1-46, the input and output voltages are in phase. This type of circuit is used when high voltage gain is desired. In B of figure 1-46, the transistor is connected in a common emitter circuit. The emitter lead is common to both the input and output circuits. The input and output voltages of this circuit are 180° out of phase. This circuit is used when a high current or power gain is desired. In figure 1-46, the transistor is connected in a common collector circuit. In this circuit, the input and output signals are also in phase. This circuit has a high input impedance and is capable of unit voltage gain. All of the above circuits are used in various controlling devices, such as voltage regulators and governor controls in power-roduction equipment.

**Exercises (215):**

1. Why does a transistor basically function the same as a vacuum tube in a circuit?

2. How can the base lead of a transistor usually be identified in a circuit?

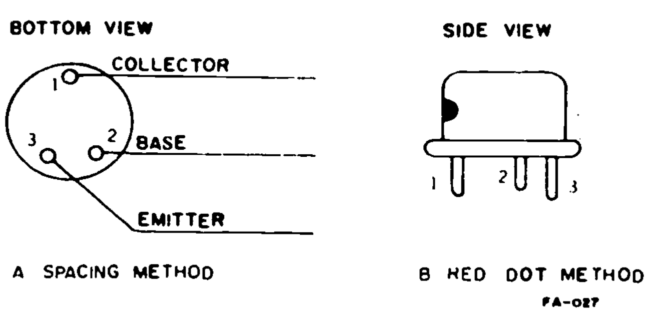



Figure 1–44. Transistor lead identification.

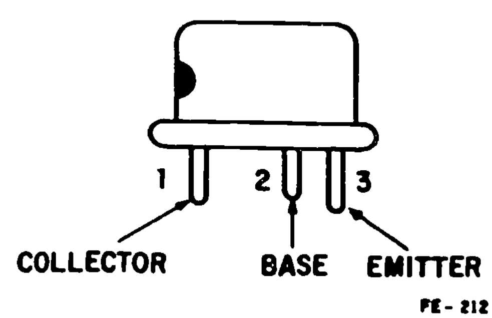



Figure 1–45. Transistor marking.

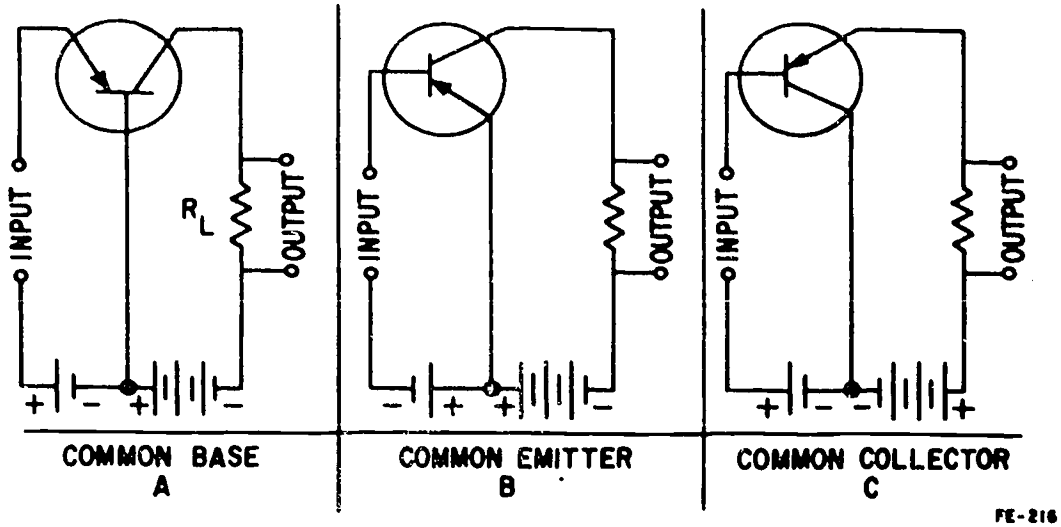



Figure 1-46. Transistor circuits.

3. How is a transistor connected in a circuit when a high voltage gain is desired?

**216. Specify the operation and use of diodes and rectifiers.**

**Diode Operation.** The diode is constructed of two elements and is a unilateral conductor. This means that it has two connections and that current will flow through it in only one direction. A junction diode is shown in figure 1-47. It consists of two dissimilar, semiconductor materials that are joined together. When the P- and N-type materials are joined, they are called P–N junctions or junction diodes. One external lead is connected to the P section and the other to the N section. Normally the N material is the emitter, and the P material is the collector. It is important to remember that a diode has a high resistance when connected in a reverse direction and a very low resistance in the forward direction.

**Rectifier (Diode).** When a diode is used as a rectifier, it may physically appear as shown in figure 1-48. The arrow indicates the direction of current flow and is printed on the side of the diode. The current flows from the top to the bottom or through the stud. This is a normal polarity rectifier diode. Other types of rectifiers are manufactured with the polarity reversed; the flow of current is then in the opposite direciton. The arrow on the case will be pointed toward the top of the rectifier. When it is necessary to change a rectifier, the polarity marks must be observed and the replacement must have exactly the same polarity.

**Silicon-Controlled Rectifier (SCR).** A silicon-controlled rectifier is a very special diode. In addition to the two normal connections of a diode, the SCR has a third connection called a gate. Figure 1-49 shows an SCR and SCR symbol. Regardless of the direction in which this SCR is connected in a circuit, it will not conduct until a voltage or current pulse is applied to the gate in proper polarity. The SCR will then conduct and keep on conducting until its input voltage drops to zero or changes polarity, or its output voltage changes polarity. Figure 1-50 shows a simple SCR switching circuit. When the switch is closed momentarily, a positive voltage is applied to the gate and forward biases the center P–N junction. The SCR turns on and remains so until the forward voltage is removed or reversed.

**Zener Diode.** A Zener diode is very much like a small rectifier. It is processed to allow a current to flow through it

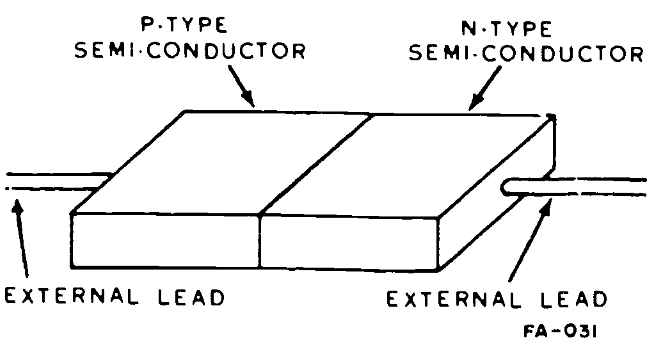



Figure 1-47. Junction diode.

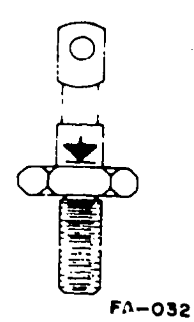



Figure 1-48. Diode rectifier.

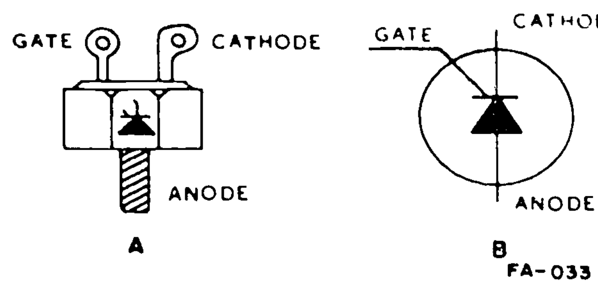



Figure 1–49. SCR and SCR symbol.

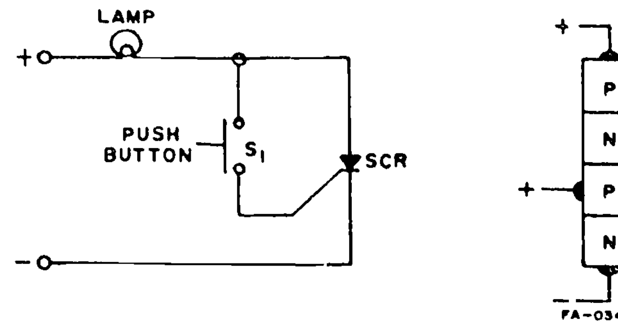



Figure 1–50. A simple SCR switching circuit.

in a direction which is reverse to the flow that would occur if it were a rectifier. Current can flow through a Zener diode in both directions. In the forward direction, current will flow at a very low voltage, usually at about 1 volt. In the reverse direction, no current will flow until the voltage impressed across it is equal to the Zener voltage. At this point, a current will flow and an extremely small increase in voltage will cause the current to increase enormously. Figure 1-51,A, shows an outline of a Zener diode, and 1-51,B, shows the electrical symbol. Note that the current flow through this device is in the reverse direction as compared to that of a normal rectifier.

**Metallic Rectifiers.** The principal metallic rectifiers are the copper-oxide and the selenium-oxide rectifiers shown in figure 1-52. Both are rectifiers, because they permit current to flow more readily in one direction than in the other. A copper-oxide rectifier consists of a thin film of copper oxide on a copper plate. This you can see in an exaggerated form in detail B. A selenium-oxide rectifier, detail C, consists of a prepared film of selenium on a metallic substance such as iron. A selenium-oxide rectifier has a somewhat lower resistance than the copper-oxide type and is, therefore, more efficient, since it can pass higher current. This type of rectifier cannot stand high voltages, because the selenium film is very thin. Therefore, an appropriate number of rectifier plates must be connected in series to withstand a given peak inverse voltage (PIV). For example, several rectifier units, as shown in figure 1-52, C, can be connected in series to increase the allowable PIV. This, of course, increases the rectifier resistance and resultant IR drop.

**Exercises (216):**

1. Why should an ordinary diode be connected in a circuit to conduct in one direction only?

2. How is the direction of current flow indicated on a rectifier diode?

3. What causes an SCR to conduct and for what duration?

4. How can metallic rectifiers be connected to withstand a higher peak inverse voltage?

5. How does a Zener diode differ from other diodes?

**2.7. Identify characteristics of magnetic amplifiers.**

**Magnetic Amplifiers.** A magnetic amplifier is a static device that controls a magnetic field to accomplish its purpose. The core and windings make it similar in appearance to a transformer. It is designed so that small changes in the input will result in large changes in the output. A saturable reactor is the basic part of a magnetic amplifier.

*Saturable reactor.* A simplified diagram of a saturable reactor is shown in figure 1-53. It has two windings on an iron core. The AC coil is called the load winding and the

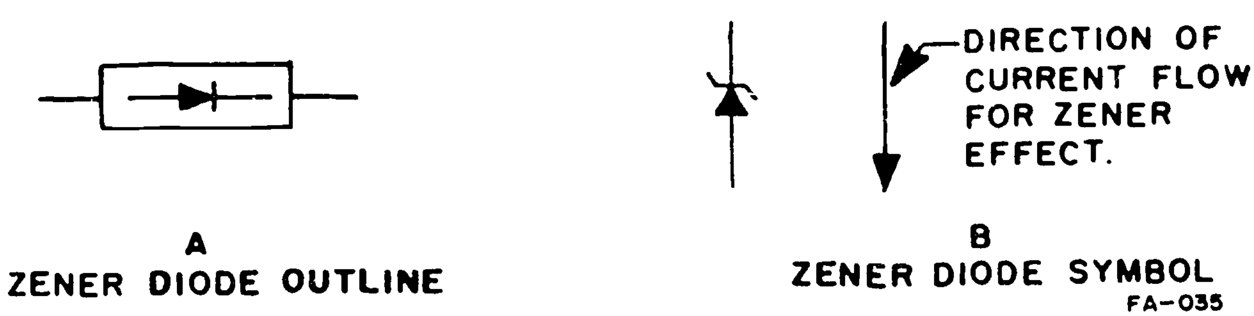



Figure 1–51. Zener diode.

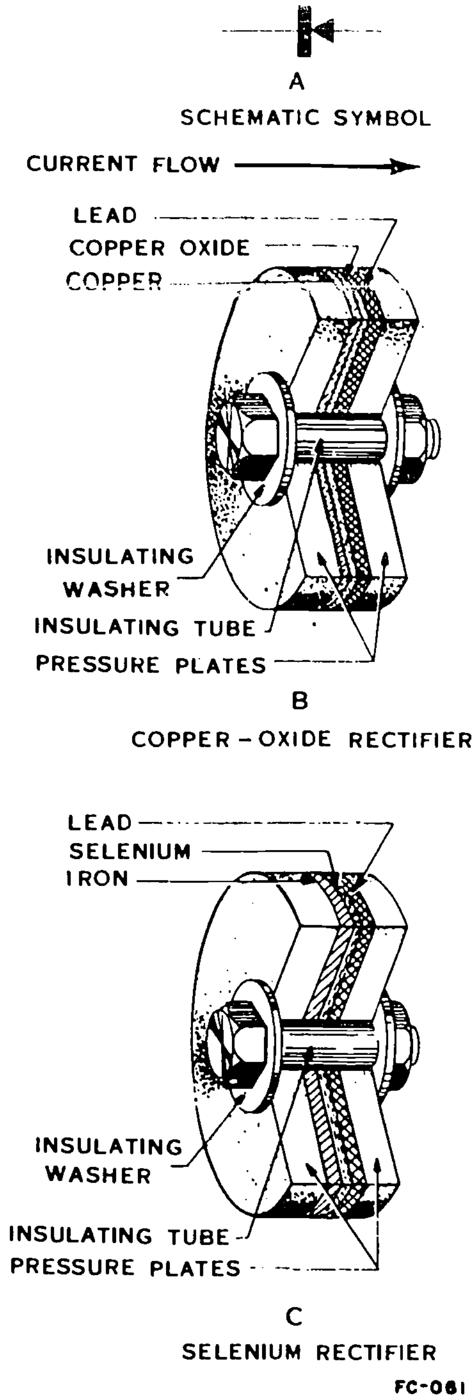



Figure 1-52. Metalic rectifiers.

DC coil is called the bias winding. The core is made of special material that can be saturated easily with a magnetic field. By turning the rheostat, the current in the bias winding can be varied. This current changes the saturation of the core, which, in turn, changes the impedance in the load winding and determines the output voltage across the load. If there were zero impedance in the load winding, the full applied voltage would be found across the load. With very high impedance in the load winding, you would have

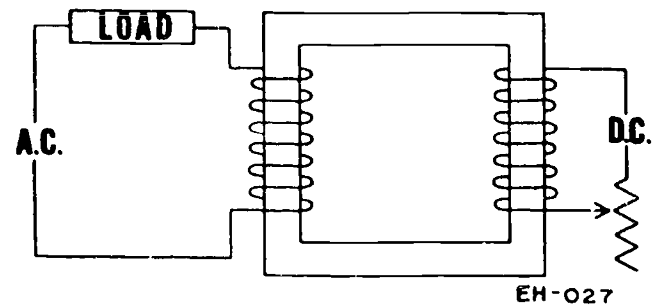



Figure 1-53. Simple saturable reactor.

very little voltage drop across the load. Remember that impedance is like resistance, and the load winding is in series with the load. The load winding acts like a variable resistance. When the core is operating near the saturation level, only a small change in the bias current is required to cause a large change in the load.

*Simple magnetic amplifier.* The addition of another winding to the core of a saturable reactor will make a simple magnetic amplifier, as illustrated in figure 1-54. This is a control winding, which is also supplied with DC and has a rheostat to adjust the current, as in the bias winding. The control and bias rheostats are adjusted to a point slightly below core saturation. The load current can now be varied by changing the control current. Increasing the control current brings the core closer to saturation and increases the load current. Decreasing the control current will cause a decrease in load current.

You should remember from your study of electromagnets that the strength of the field depends on the number of turns and the current in the coil. A coil with a great many turns and a small current can produce a relatively strong magnetic field. This is the principle that is applied to the control winding to make the unit amplify. This is the reason that a small change in control current can cause a large change in the output. Where output demands are too high for one unit, a two-stage magnetic amplifier is used. The output of the first stage supplies the control winding of the second stage. Even large generator plants have their output automatically controlled in this way.

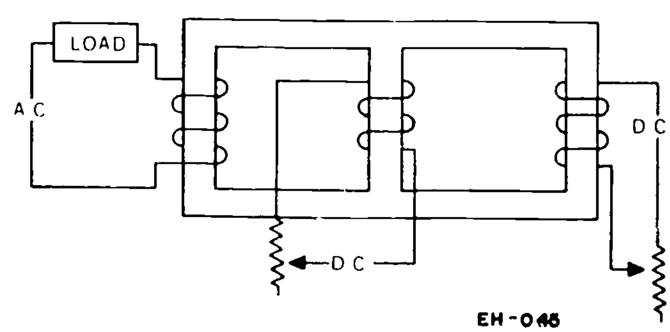



Figure 1-54. Simple magnetic amplifier.

**Exercises (217):**

Mark the following statements true (T) or false (F) in the space provided, and correct false statements.

_____ 1. When a control winding is added to a saturable reactor, it becomes a simple magnetic amplifier.

_____ 2. When the core of a saturable reactor is near saturation, a large bias current is required to cause any change to the load.

_____ 3. The DC coil is the load winding and the AC coil is the bias winding in a magnetic amplifier.

_____ 4. Increasing the number of turns and current in the control winding of a magnetic amplifier will bring the core closer to saturation quickly.

_____ 5. The control and bias rheostats are adjusted just above core saturation.

# Electrician's Tools

THE AIR FORCE electrician is primarily responsible for electrical systems installed inside buildings as opposed to the powerline specialist, who is responsible for outside distribution systems. Among your responsibilities as an electrician are the installation and maintenance of interior electrical circuits and devices. You will install, troubleshoot, and repair electrical equipment. To perform these tasks, you must know what handtools, special tools, or power tools you need and how to use them effectively.

In this chapter, we will give you information on how to select and use tools, and some safety precautions when using them. The information will be presented under the following headings: common handtools, special tools, and power tools. We also discuss test equipment.

## 2-1. Common Handtools

Regardless of the type of work to be done, you must select and use the correct handtool. Without the right tools and the knowledge of how to use them, the electrician wastes time and cuts down his or her efficiency. This efficiency in using handtools is also determined, to a great extent, by the condition in which you keep your tools. A good electrician will take care of his or her tools and will select the proper tool for the job. Therefore, we will begin by discussing the most common handtools, such as screwdrivers, pliers, wrenches, hammers, and vises.

### 218. Identify functions and uses of selected common handtools.

**Screwdrivers.** The screwdriver is one of the most common handtools; because it is so common, everyone thinks he or she knows how to use it properly. It usually winds up being the most abused tool. Some of the abuse is a result of not knowing the type or proper use of the tool.

*Types, use, and selection.* There are several types of screwdrivers. However, there are two main types of screwdriver blades: the Phillips (crosspoint or cross slot) and the standard (common) blade. Each type is designed to fit a particular type of screw, as shown in figure 2-1. Within each there are several sizes and shapes. The size is measured from the base of the handle to the tip of the blade, which is called the shank. The common sizes are 3, 4, 5, 6, 8, 10, and 12 inches. The shape can be an offset, straight, or flared tip. The offset shape can be a standard or crosspoint blade. See figure 2-2 for examples of various sizes and shapes of screwdrivers. The types that you will use most are the standard straight or flared tip, and the crosspoint.

The standard screwdriver is used where the screw or bolt is slotted in the standard manner. The crosspoint is used only on screwheads or boltheads that are cross slotted. The offset is used when it is impossible to get at a screwhead with a standard or crosspoint screwdriver because of the small clearance.

Use screwdrivers only for the job for which they are designed —to drive and remove screws. Never use the screwdriver as a prybar or chisel. If you do, you are likely to break the blade. When you turn a screw, hold the screwdriver firmly against the screwhead; do not hold the blade at an angle in the screwhead. If you do, you are likely to break the blade or the screwhead. Never use pliers or a wrench on a screwdriver blade. Apply force on the handle with your hand. Figure 2-3 illustrates the right and wrong uses of screwdrivers. These illustrations apply to all types of screwdrivers.

When selecting a screwdriver for a job, select the type and size that will fit the screw. The blade tip must have sharp corners and fit the screw closely. If you use a standard screwdriver that is too small, you will probably ruin the slot in the head of the screw. You may also bend or break the screwdriver blade. See figure 2-4 for right and wrong fitted standard screwdrivers. The same holds true for crosspoints—use a screwdriver that fits the screw.

When a screwdriver blade tip becomes rounded, nicked, or broken, you can usually restore it to the original shape with a grinder or file. The tips should be ground or filed so that the sides are parallel to keep them from slipping out of the screw slot. It is also good practice to slightly hollow-grind the sides of the blade, as shown in figure 2-5. This puts the tip of the blade at the bottom of the screw slot, making it easier to drive and remove screws without damaging the screwhead.

To remove the nicks or sharpen a screwdriver, file or grind the tip until the nicks are removed and the tip is squared. Then shape the faces and sides by grinding lightly on the side of the emery wheel or by filing. To keep from overheating and destroying the temper of the blade, dip the tip in water between short periods of grinding. Do not remove any more material than is necessary.

The crosspoint screwdriver must be treated in a different manner. In restoring the crosspoint screwdriver to its original condition, apply a three-cornered file to remove any burrs that exist on the damaged tips. Due to the delicacy of its fine blades, the Phillips screwdriver has to be discarded whenever the blades are damaged beyond the filing point.

**Pliers.** Each pair of pliers is designed for a specific job. There are cutting, gripping, or holding types consisting

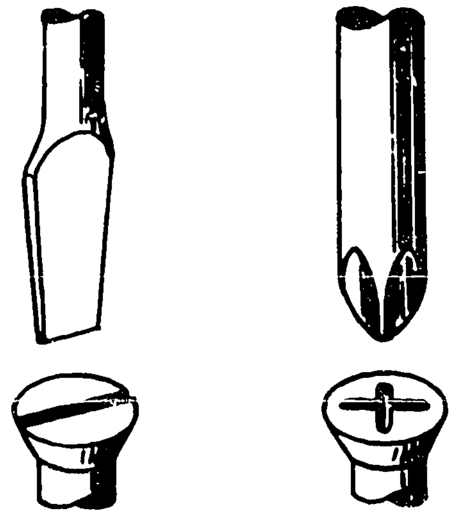



Figure 2–1. Screwdriver blades.

mainly of a pair of jaws, a pivot point, and a pair of handles. The types used most often by the electrician are the diagonal, sidecutters, longnose, combination slip-joint, and water pump pliers. These types are illustrated in figure 2-6.

*Types and use.* The sidecutting pliers and diagonals are of the cutting types. The diagonals are for close cutting, while the sidecutters are used for much heavier cutting of larger wire and small cables. In addition to cutting wire, the sidecutters are used for holding wire while bending or twisting, and are often used to strip the insulation from wires.

The combination slip-joint and water pump pliers also are used in electrical work. They are used to grip flat or round stock and to bend small pieces of metal to desired shapes. The water pump pliers are made with extra long handles for increased gripping power. Both types of pliers are adjustable to several positions for handling objects of various sizes. Longnose pliers also serve many useful purposes. They may be used to bend an eye or loop in solid wire so that it can be placed under a bolthead or screwhead. In places where you cannot get your fingers to place or tighten wires, the proper application of the longnose pliers will be helpful. These pliers are actually extensions of your fingers in many instances.

Do not use pliers as an all-purpose tool. They are not to be used as a wrench for tightening nuts or boltheads, for example. Pliers round the corners on nuts or boltheads so that a wrench cannot get a firm grip. Do not use pliers as a prybar or as a hammer, because you may bend or break the handles. Do not attempt to cut extremely hard objects, because such action will nick or dull the cutting edges of the jaws.

*Selection and care of pliers.* You must use good judgment in selecting pliers for a job. You must make sure the pliers are large enough for the job. Pliers are made in a wide range of sizes to avoid overstraining and breaking the tool. Not only must you select the proper size tool, you must also select the right tool for the job. For example, you would not use diagonal pliers to hold a piece of round stock. Select the right size and type of pliers for the job and cut out the lost time used for extra care of the tool.

The care of pliers usually involves cleaning, pivot- point maintenance, and sharpening the cutting edges. Pliers require an occasional oiling at the pivot points or joint. After pliers are used for some time, the pivot point often becomes loose and must be tightened. Some pliers have a nut that can be tightened; others have a solid pin that must be tightened by laying the pliers on an anvil and striking the pivot lightly with a hammer. Cutting pliers at times may become pitted at the cutting edge. The proper use of a fine file over a pitted spot on the cutting edge is sufficient to restore its original condition. You can also use the fine file

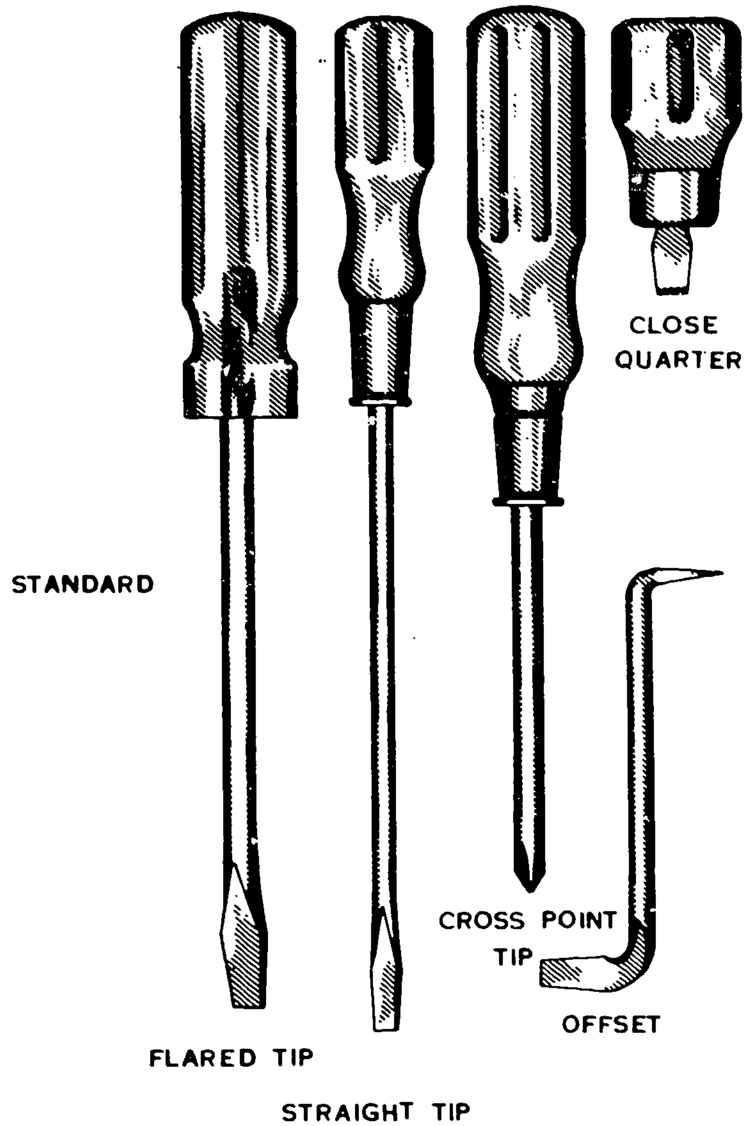



Figure 2–2. Screwdrivers.

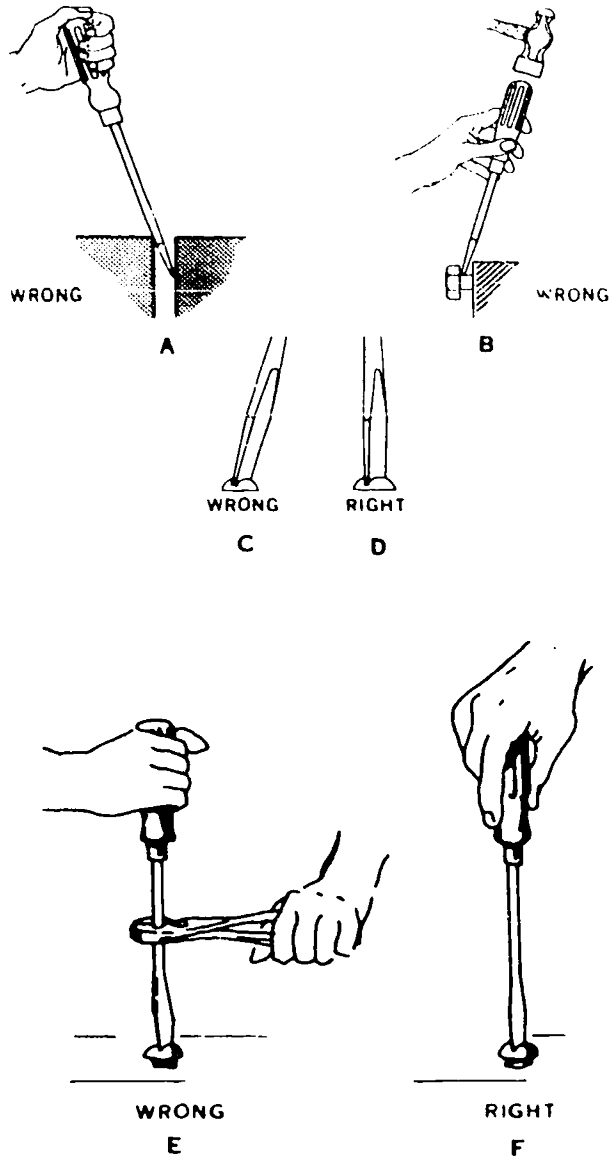



Figure 2–3. Use of Screwdrivers.

to sharpen the cutting edge of the diagonals or sidecutters, if necessary. The knurled jaws or gripping teeth of the holding pliers require cleaning for better gripping. Use a steel brush to clear out steel wastes, paints, or grease that has piled up on the teeth or knurled jaws.

**Wrenches.** Some wrenches are used for tightening and loosening bolts and nuts; others may be used for turning round materials, such as conduit and pipes. The more common wrenches you use in your work are shown in figure 2-7.

*Types and use.* The pipe wrench has a knurled drive wheel to adjust the space between the jaws. The movable jaw is spring loaded so that it will bind or lock when it pulls on a pipe. If you reverse the direction of pull, the jaw releases its hold. You use a pipe wrench to assemble threaded conduit and coupling. The adjustable open end wrench has a spiral drive wheel to adjust the jaws. You must adjust the wrench so that the jaws fit snugly on a nut before you apply pressure to turn it. If the jaws fit loosely, the wrench may slip and damage the nut. As a rule, adjustable wrenches are suitable for heavy-duty work. Open end wrenches fit standard-sized nuts. They are lightweight, strong, and convenient for doing work in limited space. Because the jaws are usually set at 15° or 90° angles, it is easy to w ' in close places by turning the wrench over after each movement. The length varies according to the size of the opening. Some open end wrenches are angular in construction. Box end wrenches are preferred over the open end and adjustable- jaw wrenches. They are safer to use and are less likely to slip off a nut or bolthead. Box end wrenches may be used only on hexagon nuts and boltheads. This wrench cannot be used to turn a square nut or bolthead. The strap wrench is used on brass, copper, and chromium-plated pipes and fittings, because it will not scratch or mar the finished surfaces. It has a thick canvas strap instead of a chain or jaws to grip the pipe. The chain wrench is also used on pipes and fittings. It is placed on the pipe by wrapping the chain around the pipe and attaching it to the wrench by a slot arrangement. The advantage of a chain wrench is that it will grip and apply an even pressure all the way around the pipe or fitting, where a large conventional pipe wrench grips the pipe only at two points. The chain wrench is much safer to use than the conventional pipe wrench, because it will not slip off the pipe.

When using a wrench of any kind, always try to pull on it; it is usually dangerous to push on it. Figure 2-8 shows the right and wrong way to use an open end wrench. When using an adjustable wrench, if the pulling force is applied to the adjustable jaw, the wrench is likely to slip or break. Figure 2-9 shows the right and wrong procedures for using adjustable jaw wrenches. Never use a pipe to increase leverage. The handle is not designed for this and will bend or break.

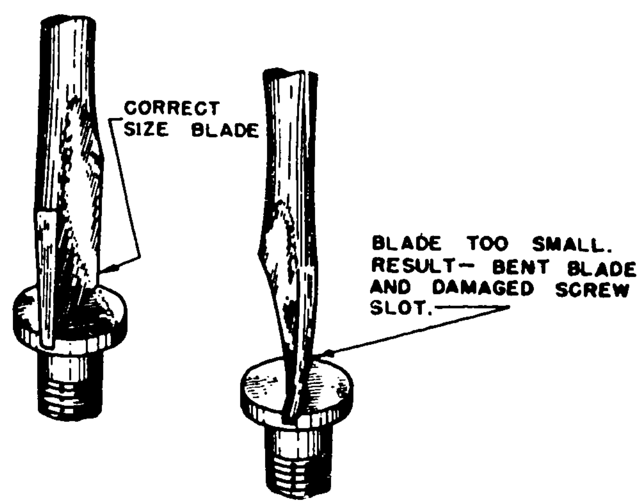



Figure 2–4. Blade fit (thickness).

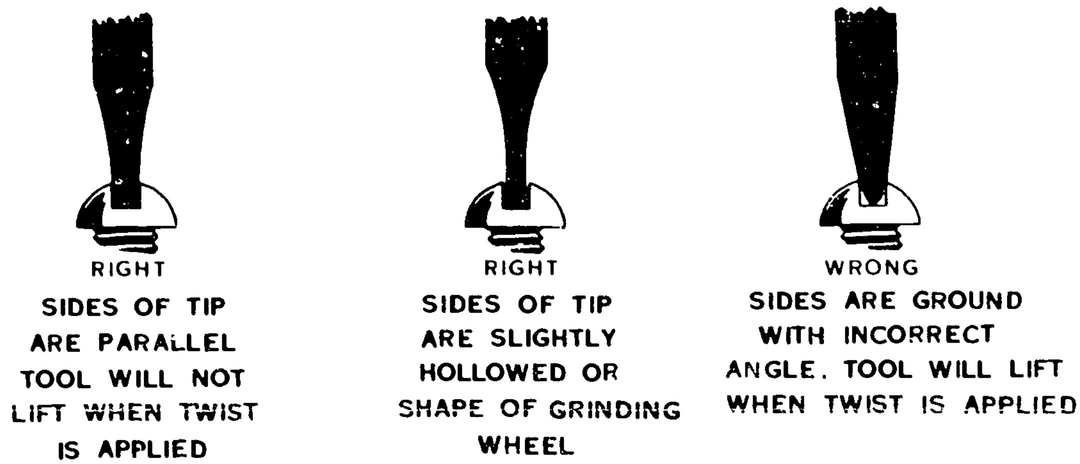



Figure 2–5. Blade tip shape.

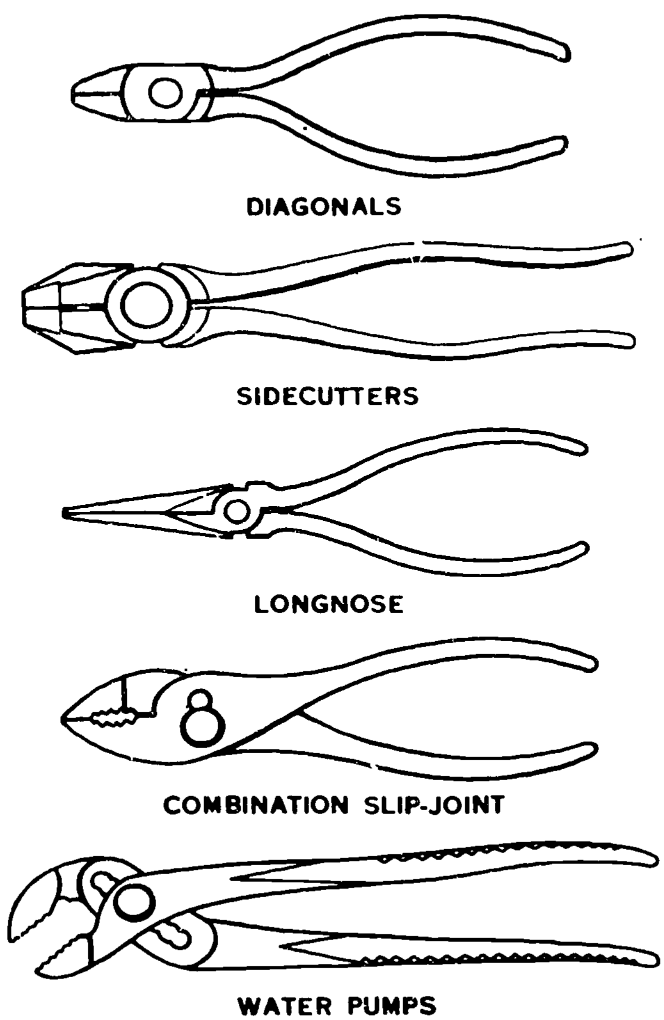



Figure 2–6. Pliers.

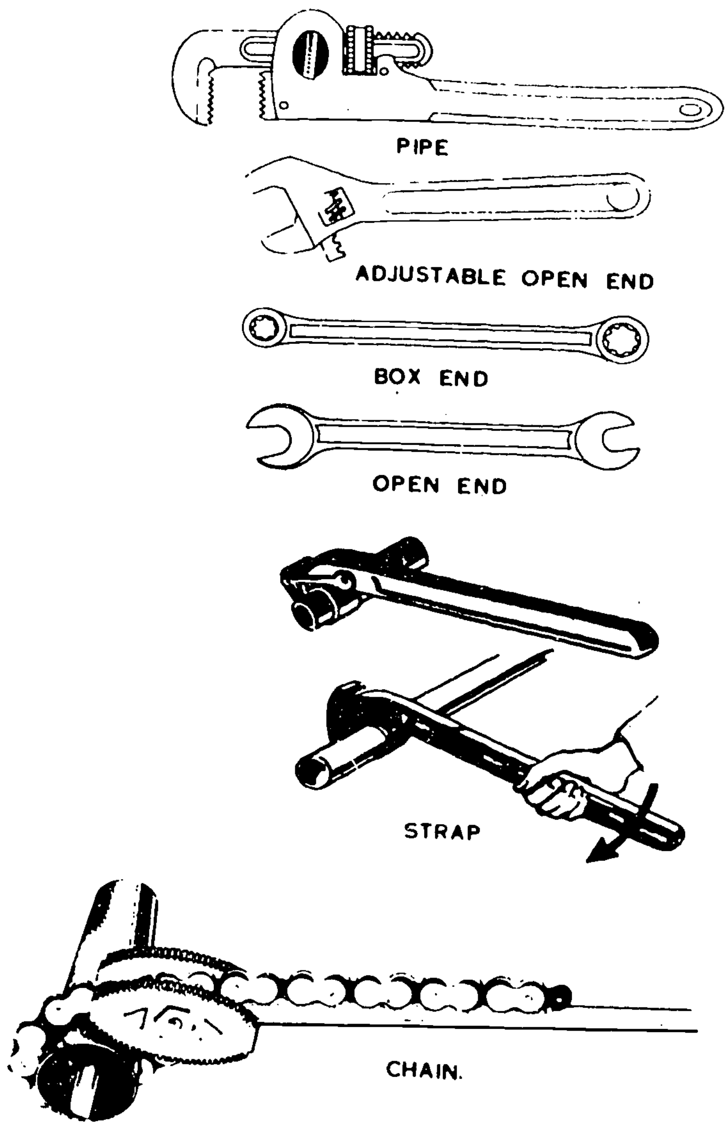



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Figure 2–7. Wrenches.

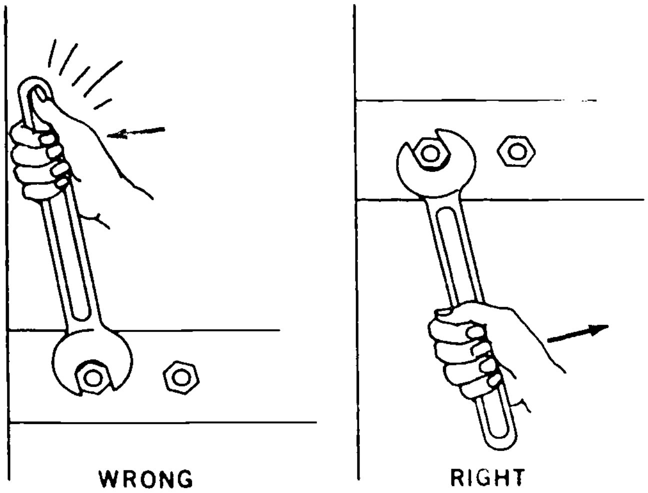


Figure 2–8. Proper use of open end wrench.

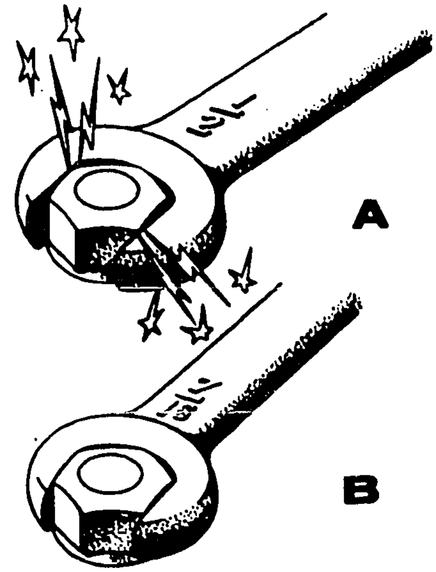


Figure 2–10. Select correct wrench size.

*Selection and care*. All of the wrenches have special advantages. For example, the open end wrench is used where space is limited or where a straight wrench cannot be used. The box end wrench is safer to use and is less likely to slip off the nut. However, the box end cannot be used on the standard square nuts. The adjustable wrenches are used only when other wrenches do not fit. The pipe wrench is used to assemble conduit and couplings. In this case, though, the strap and chain wrenches are much safer to use than the conventional pipe wrench because they will not slip off the pipe. A good electrician chooses the one best suited for the job and also selects the correct wrench size, as illustrated in figure 2-10.

All wrenches must be kept clean and free of rust. Wash any grease and dirt from wrenches with drycleaning solvent. Any rust spots should be removed with crocus cloth or steel wool. Wipe down your wrenches periodically with a clean cloth dipped in a light grade of lubricating oil.

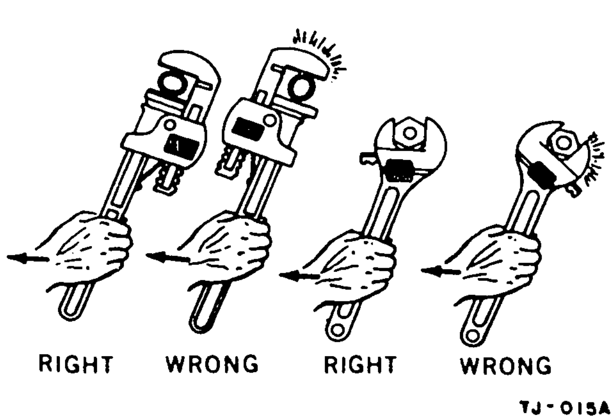


Figure 2–9. Proper use of adjustable jaw wrenches.

Lubricate the worm adjustment on pipe wrenches and adjustable jaw wrenches with few drops of oil. Never use a wrench that has battered, chipped, or sprung jaws. Wrenches that have bad defects should be taken out of service.

**Hammers.** Hammers are made in various sizes, shapes, and types. Each type is designed for a specific type of work. Some types are used for driving nails; other types are used for metalforming or to drive a chisel or punch. Yet another type is designed for use where a steel hammer might mar or damage the work. You will find that you use the claw hammer and the ball-peen hammer more than any other types. Figure 2-11 shows some hammers and mallets with which you should be acquainted.

*Types and use*. The claw hammer is used to drive or pull nails in wood construction. When driving nails, hold the claw near the end of the handle with the face of the striking surface parallel to the work, as illustrated in figure 2-12. Do not hold the hammer near the neck or head. A grip just tight enough to control the tool is best. Deliver blows upon the object by raising the arm and hammer in a smooth arc away from the object and then bring the hammer down with a quick, sharp motion. The ball-peen hammer is used mainly in mechanical and shipwork. Use it with driving and cutting tools, such as punches and chisels. The manner in which you use a ball-peen hammer is the same as for the claw hammer. The mallet is a hammer used mainly at a workbench for tapping on more delicate equipment. Mallets are handy for disassembling motors and other electrical equipment. Mallets come with plastic, hard rubber, or pressed leather heads, and are generally lightweight. Another hammer you sometimes have need for is the sledge hammer. It has a double-faced head and is used for heavy work, such as driving stakes and ground rods. It can also be used for breaking concrete.

*Selection and care.* Since each type of hammer is designed for a specific type of work, you should select the right hammer for your work. For example, you should not use a ball-peen hammer or a mallet to drive a nail; nor should you use a sledge hammer. You sh use a claw hammer. Likewise, you should not use a c w hammer to drive a large ground rod; you should use a edge hammer. You should use a mallet to assist in the .sassembly of a motor. Whichever hammer you use, make sure the tool is in good condition.

Always inspect a hammer before you use it. Never use any hammer if the head is loose on the handle. Hammer handles that are cracked or split must be replaced. Do not attempt to repair a handle by wrapping tape around it.

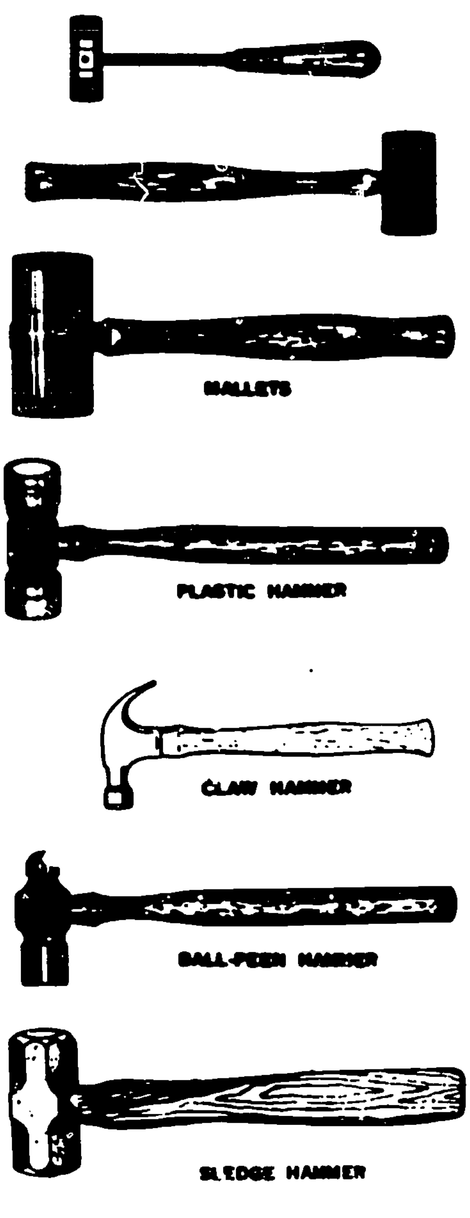


Figure 2-11. Mallets and hammers.

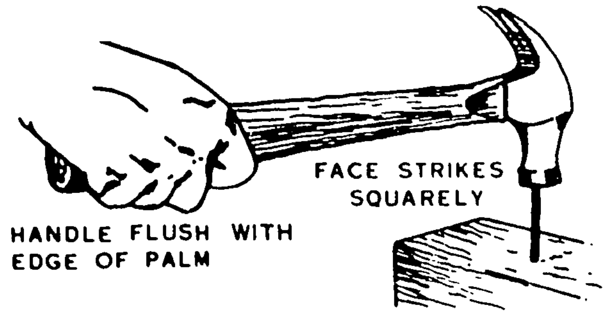


Figure 2-12. Nail driving (claw hammer).

**Vises.** There are several types of vises at the electrician's disposal. Figure 2-13 shows four of the more common types—the machinist's vise, the utility vise, the chain vise, and the pipe vise. The machinist's and utility vises are bench mounted and very similar in design. The machinist's vise has flat jaws and a swivel base and is suitable for most ordinary shopwork. The utility vise has removable soft-jaw inserts and is equipped with pipe jaws. For this reason, the utility vise is more versatile because it will grip pipe or round rods. When working with a polished metal, use the soft-jaw inserts. The conventional pipe vise is a quick-release type that can be mounted either on a shop bench or on portable legs and carried to the job site. As you can see in figure 2-13, the chain-type vise grips the pipe by a chain arrangement. The pipe and chain vises are used when cutting and threading conduit.

Vises require very little maintenance other than keeping them clean and the movable parts well oiled. Do not use the jaws of a vise as an anvil. There is a danger of breaking the jaws or battering the inserts. Never use a pipe to increase the handle leverage, because excessive pressure on the handle may break the handle or jaws.

**Exercises (218):**

1. Match the descriptive statements in column A to the correct tool in column B by placing the appropriate letter in the provided blank. Some letters may be used more than once.

| Column A | Column B |
|---|---|
| _____(1) Has removable soft-jaw inserts and pipe jaws. | a. Screwdrivers. |
| _____(2) Used for forming wire loops. | b. Longnose pliers. |
| _____(3) Used for driving and removing screws. | c. Pipe wrench. |
| _____(4) Uses a chain to grip its work. | d. Adjustable jaw wrench. |
| _____(5) When turned backwards, releases its grip. | e. Claw hammer. |
| _____(6) Used for driving or pulling nails. | f. Box or open end wrench. |
| _____(7) Used for turning nuts and bolts if the right size box or open end wrench is not available. | g. Sledge hammer. |
| _____(8) Comes in standard sizes to fit nuts and bolts. | h. Utility vise. |
| | i. Chain vise. |
| | j. Sidecutting pliers. |

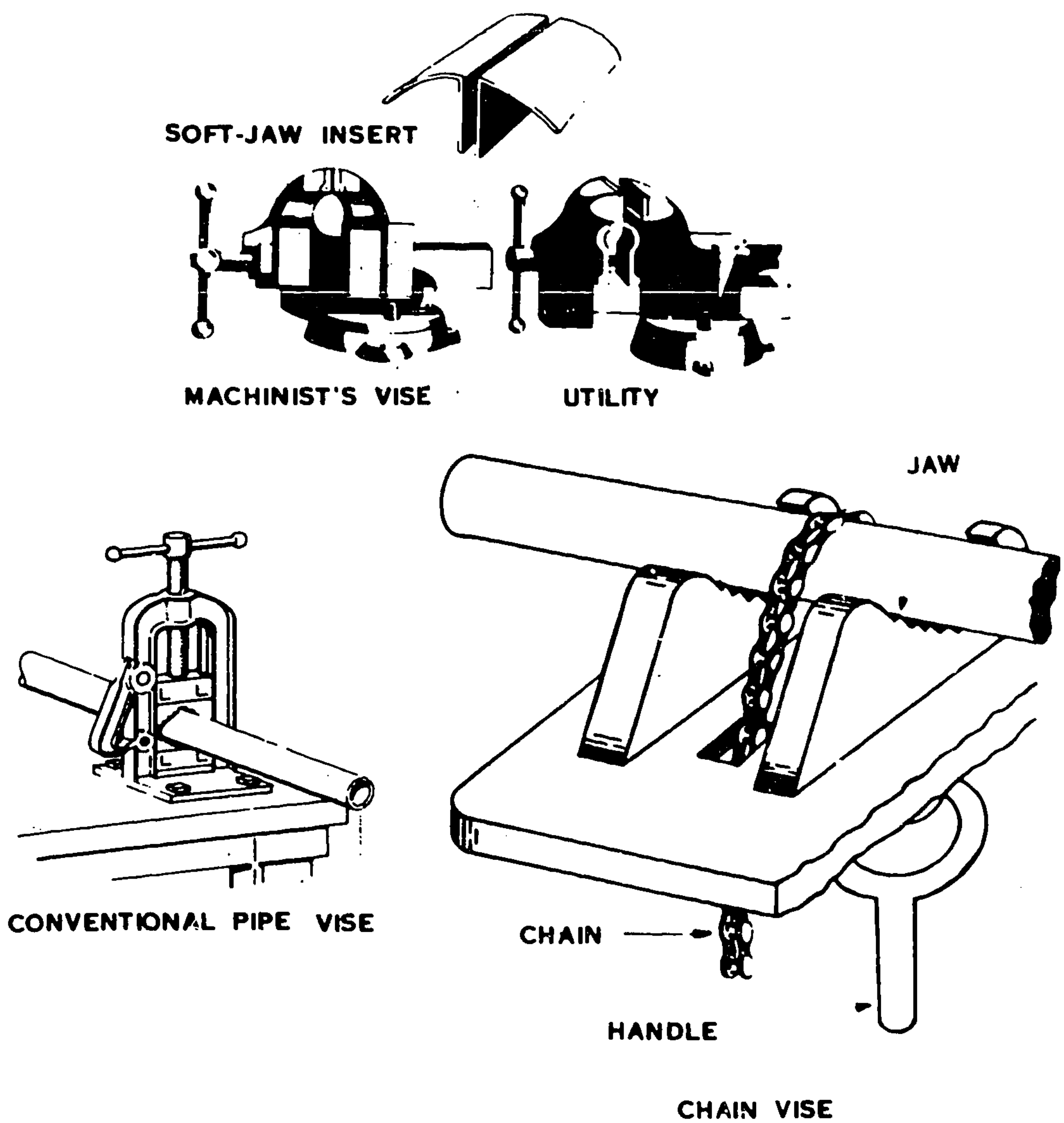


Figure 2-13. Vises.

| | *Column A* | *Column B* |
|---|---|---|
| ______(9) | Used to assemble conduit and couplings. | k. Conventional pipe vise. |
| ______(10) | Used to cut large wire and small cables. | l. Water pump pliers. |
| ______(11) | Can be mounted on legs and carried to the job sites. | |
| ______(12) | Equipped with adjustable jaws and extra-long handles for gripping round stock. | |
| ______(13) | Used for driving stakes and ground rods. | |
| ______(14) | Should not be used for a chisel or punch. | |

**219. Identify functions and uses of selected cutting and boring tools.**

In many cases, you must cut or drill openings in walls, floors, and ceilings for installation of electrical units. You will use cutting and boring tools to do this job.

**Cutting Tools.** There are several types of cutting tools used by the electrician. Among these tools are the carpenter's saw, hacksaws, conduit cutters, knockout punch, pocketknife, and chisels.

*Carpenter's saw.* The carpenter's handsaw, illustrated in figure 2-14, is available in two types—the ripsaw and the

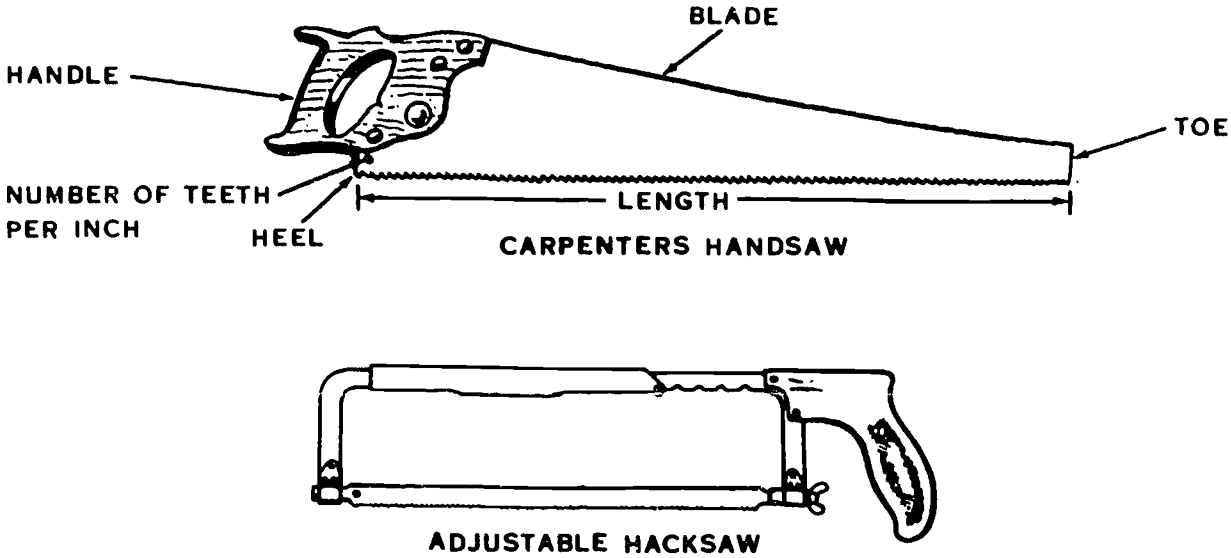


Figure 2-14. Saws.

crosscut saw. The length of the cutting edge determines the size of the saw. These saws range in size from 18 to 26 inches. The ripsaw has coarse teeth and is used for sawing wood with the grain. The crosscut saw has fine teeth and is used for sawing wood across the grain. Although the carpenter's saw is designed for sawing wood, it may also be used for sawing plastic. The teeth are fixed so that they cut on the downward (away from your body) stroke only. Be sure there are no nails or other edge-destroying objects in the way. If you are sawing out a strip of waste, do not break out the strip by twisting the saw blade. This action dulls the saw and can spring the blade. Hang up the saw when it is not in use to avoid contact with other tools, and keep the saw coated with light oil to prevent rust.

*Hacksaws*. The hacksaw, one type of which is shown in figure 2-14, is used for cutting metal. Most hacksaws have adjustable frames that use blades from 8 to 16 inches in length. Several varieties of hacksaw blades are available. They differ in the hardness of the blade and the number of teeth per inch. A hard blade is best for sawing brass, tool steel, or cast iron; a flexible blade is better for cutting hollow shapes and metals of light cross section, such as tubing, tin, or copper conduit. The teeth range from 14 to 32 teeth per inch. In general, use a coarse-toothed blade for sawing soft metal and a fine-toothed blade for sawing hard metals. Two or more teeth should be in contact with the work to prevent stripping the teeth.

After you have selected the correct blade, insert it in the frame with the point of the teeth pointed away from the saw handle. Sawing is done by moving the saw forward with a light, steady stroke. At the end of the stroke, relieve the pressure and draw the blade straight back. After the first few strokes, make each stroke as long as possible without striking the saw frame against the work. Always keep the saw in line with the cut being made and do not bear down on the backstroke. (Doing so may crimp and break the blade.) If the blade breaks, it can cut your hand. Do not push down on a hacksaw to try to make it cut faster. The weight of the saw should be sufficient to cause the blade to bite into the metal. Keep the hacksaw clean and stored where the blade is protected from becoming dull or broken. Dull hacksaw blades cannot be sharpened; they must be replaced.

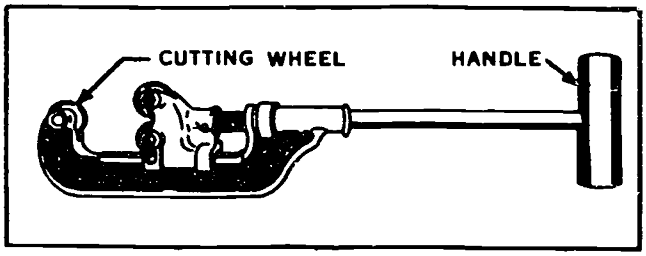


Figure 2-15. Rigid conduit cutter.

*Rigid conduit cutters*. Rigid conduit cutters, like the one shown in figure 2-15, are available in several sizes. The size usually is indicated on the frame of the cutter. A cutter with a range from 1/2 inch to 2 inches will cut a pipe up to 2 inches in diameter. Do not cut thin-wall conduit with a rigid conduit cutter. To do so flattens the ends of the conduit and reduces the inside diameter. As for care, keep the wheel pins and the threads on the shaft of the handle well oiled. When the cutter wheel becomes dull, you should replace it with a new wheel. Keep the tool clean at all times.

*Knockout punch*. The knockout punch shown in figure 2-16 is used for enlarging holes in metal. The tool will handle metal thickness up to 1/8 inch. You will use the tool to punch holes in steel cabinets, panels, and boxes, for the

installation of conduit. The diameter of the holes cut by the various punches will allow various size conduit to fit the opening. For example, a punch that will cut a hole 1 11/32 inches in diameter is used for a 1-inch conduit. Punches that cut 7/8-, 1 3/32 -, 1 11/16-, 1 15/16-, 2 3/8-, 2 7/8-, and 3½-inch holes are for 1/2-, 3/4-, 1¼-, 1½-, 2-, 2½-, and 3-inch conduit respectively. The size of the conduit to be connected will determine the size punch to use.

To use the tool, you must first have a hole in the material to be punched. The hole must be large enough to accommodate the drivebolt of the knockout. The hole should be drilled with an electric drill and twist bit. The drivebolt for the 1/2 inch conduit punch normally will require a 3/8-inch hole. Larger knockouts will require a 3/4-inch hole. Once the hole for the drivebolt is drilled, you must insert the drivebolt through the top part (die) of the knockout and then through the hole in the box. The bottom part (punch) of the knockout is then threaded onto the drivebolt until both parts, the die and punch, are tight against the box, as shown in figure 2-16.A. Now, use a wrench and turn the drive bolt to punch the hole, as shown in figure 2-16.B. Turn the bolt until you feel or hear two distinct snaps of the metal. This lets you know that the hole has been punched and the slug is free from the box. Do not tighten the drivebolt after the slug is free because you may damage the cutting edge of the punch. Now, remove the tool from the work and remove the slug from the die part of the tool. You may need a punch and hammer to tap the slug from the die.

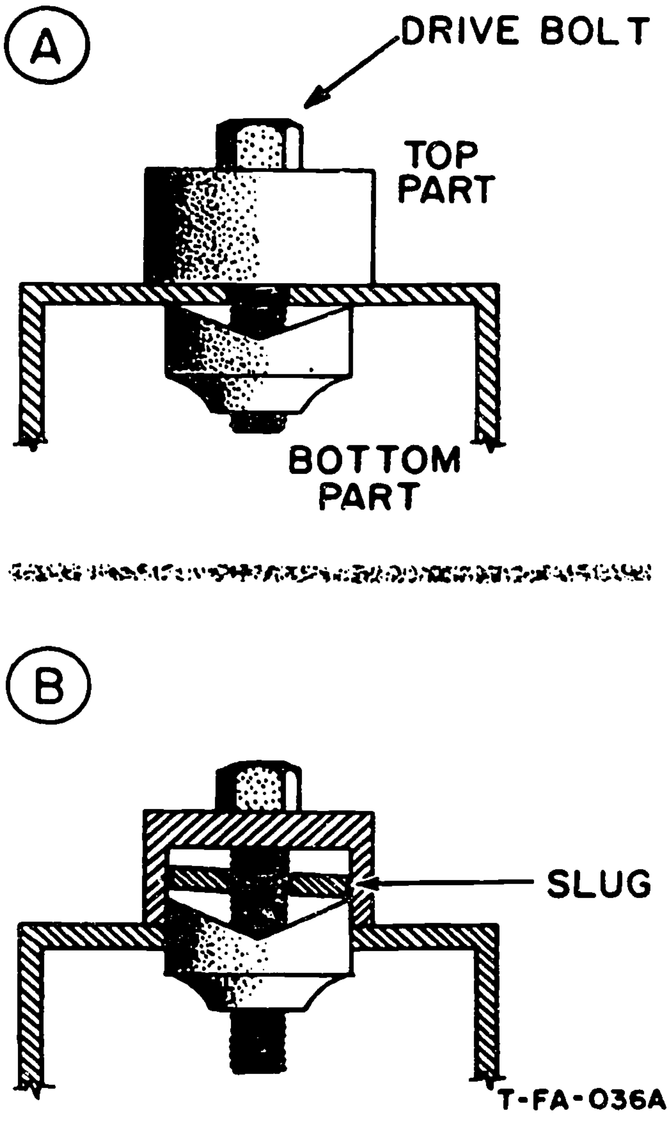

Figure 2-16. Knockout punch.

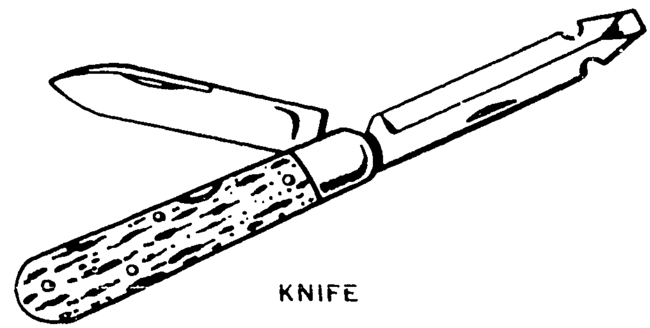

Figure 2-17. Electrician's pocketknife.

The tool can be sharpened when it becomes dull. However, this action is an emergency measure. Your concern with the care of the knockout punch, then, is limited to keeping the tool clean and well oiled.

*Pocketknife.* The electrician's pocketknife (fig. 2-17) serves many purposes. It consists of a regular cutting blade and a screwdriver-type blade. The cutting blade may be used to strip insulation from wires and to scrape the thin coat of varnish insulation from a copper conductor when making splices or connections. The screwdriver-type blade may be used to turn screws. When the knife is not in use, fold and place it in your toolbox. Knives should not be used as prybars, and the blades should be kept sharp and free of nicks.

*Cold chisels.* Cold chisels are used to cut or chip metal. The flat chisel, like the one shown in figure 2-18, is used by the electrician to shear nuts or boltheads that are frozen to where a wrench cannot remove them. This flat chisel is also used to cut sheet metal. Keep the cutting edge sharp and ground to the original angle. The hardness or softness of the metal to be cut determines the cutting angle required. A cutting edge angle of 60° to 70° is fine for most light metals. An angle of 90° is recommended for hard and tough metal. The chisel must be kept sharp and the edge slightly rounded, as shown in figure 2-18.

To use the chisel, place the cutting edge on the mark where the cut is desired and at whatever angle will cause it to follow the desired finished surface. Strike the chisel head squarely with a hammer. Start with a few light blows to get the cutting started, then let the hammer fall with more force. After each blow, lift the chisel, check the cut, and set the chisel back in the cut for the next cut. Make sure the hammer does not slip off the end of the chisel and injure your hand. When the cutting edge of a chisel becomes dull.

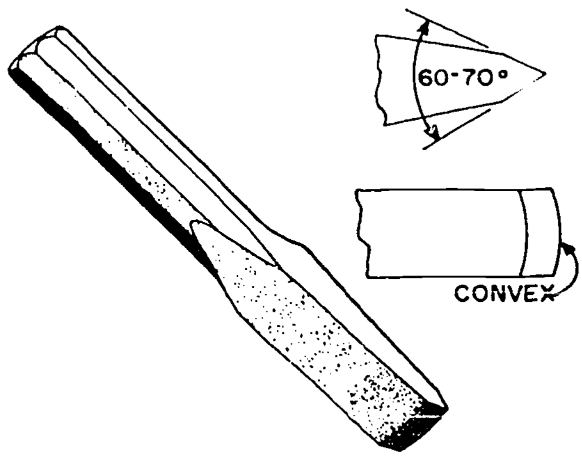

Figure 2–18. Cold chisel.

sharpen it with a bench grinder. To grind a chisel, set the rest on the grinder to secure the desired bevel angle. Move the chisel head from side to side a little during the grinding operation to slightly curve the cutting edge. Turn the chisel over and grind the hammered end to its original shape. It is dangerous to use a chisel with a mushroomed head, because steel pieces can fly off the chisel and cause injury. An example of a mushroomed chisel head and also a properly dressed head are shown in figure 2-19. When the chisel is not in use, it should be stored in a wooden box. Scour off any rust with light lubricating oil.

*Wood chisels.* The wood chisel is used to cut holes and grooves in lumber and other soft building materials. The chisel is a flat piece of steel with one end ground to an acute bevel to form a cutting edge, as shown in figure 2-20. Some of the chisels are driven by hand pressure; others are driven with a mallet. Never use a hammer or metal tool to drive the chisel. Drive wood chisels outward, away from the body, with a rubber or rawhide mallet. Do not use a wood chisel as a pry or wedge. The steel is hard and brittle, and may snap. Never place chisels on a workbench or on a shelf so they can roll off and drop on the floor, because they can be kicked or dropped on a worker's foot, causing severe injury. Keep chisels on a rack so the sharp edges will be protected.

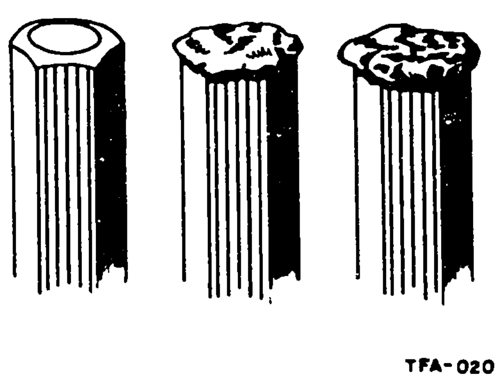

Figure 2–19. Properly dressed and mushroomed chisel heads.

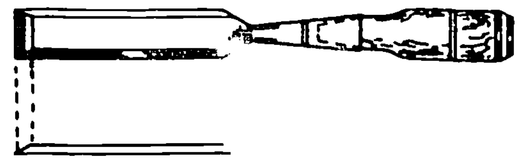
Figure 2–20. Wood chisel.

Wood chisels must be kept sharp to prevent injury to the user. Use an emery wheel to sharpen a wood chisel and then hone it on an oilstone. Secure the oilstone to a bench. Do not hold it in your hand because the sharp edge slipping off the face of the stone can cause a severe hand or wrist injury. Handles for wood chisels are made of wood or plastic.

**Boring Tools.** During the installation of electrical units, the electrician will need to bore holes in various materials. This is a simple job that involves the use of common hand drills, twist bits, auger bits, and star bits.

*Common hand drills.* The most common hand drills you will use are the ratchet brace and the hand and breast drills. Check the types of drills in figure 2-21. The ratchet brace consists of a knob, crank, and chuck for holding the bit. The chuck usually has a ratchet that allows the handle to turn in either direction to turn the chuck. This permits the boring of holes in places where a full revolution of the crank cannot be made. The chuck is built to hold only auger bits that have a square tang and is used for drilling holes in wood. Both the hand drill and the breast drill use a wheel with a handle to drive the bit. The chuck on these two drills holds a straight-shank bit, called a twist bit.

To drill with the brace, place the bit on the work and turn the handle clockwise, using a light, but firm, pressure on the head of the brace. Heavy pressure can cause the bit to break from overheating or cause the hole to be drilled oversize. The bit should be perpendicular to the work at all times. When using the hand or breast drill, the procedures are generally the same as when using a brace. Hold the hand drill with one hand on the handle and operate it by turning the crank with the other as illustrated in figure 2-22. The pressure is applied with the hand. To apply pressure to the breast drill, the operator pushes against the end of the tool with his or her body. Keep the drills clean and the moving parts well oiled.

*Auger bits.* Auger bits are screw-shaped tools with six parts and are used only for drilling holes in wood. Figure 2-23 illustrates the six parts of the bit. When you turn the brace, the spurs score a circle and the two cutting edges shave the wood from within the scored circle. The screw centers the bit and draws it into the wood. The twist carries the cuttings away from the cutters and deposits them in a mound around the hole.

*Twist bits.* Both the electric and the manually operated hand drill and the breast drill require twist bits. Most twist bits have a round shank that fits the jaws of the drills. Some twist bits are made with a tang to be used in a brace. Both types are shown in figure 2-24. The size is marked on the shank or tang and usually is given in fractions of an inch.

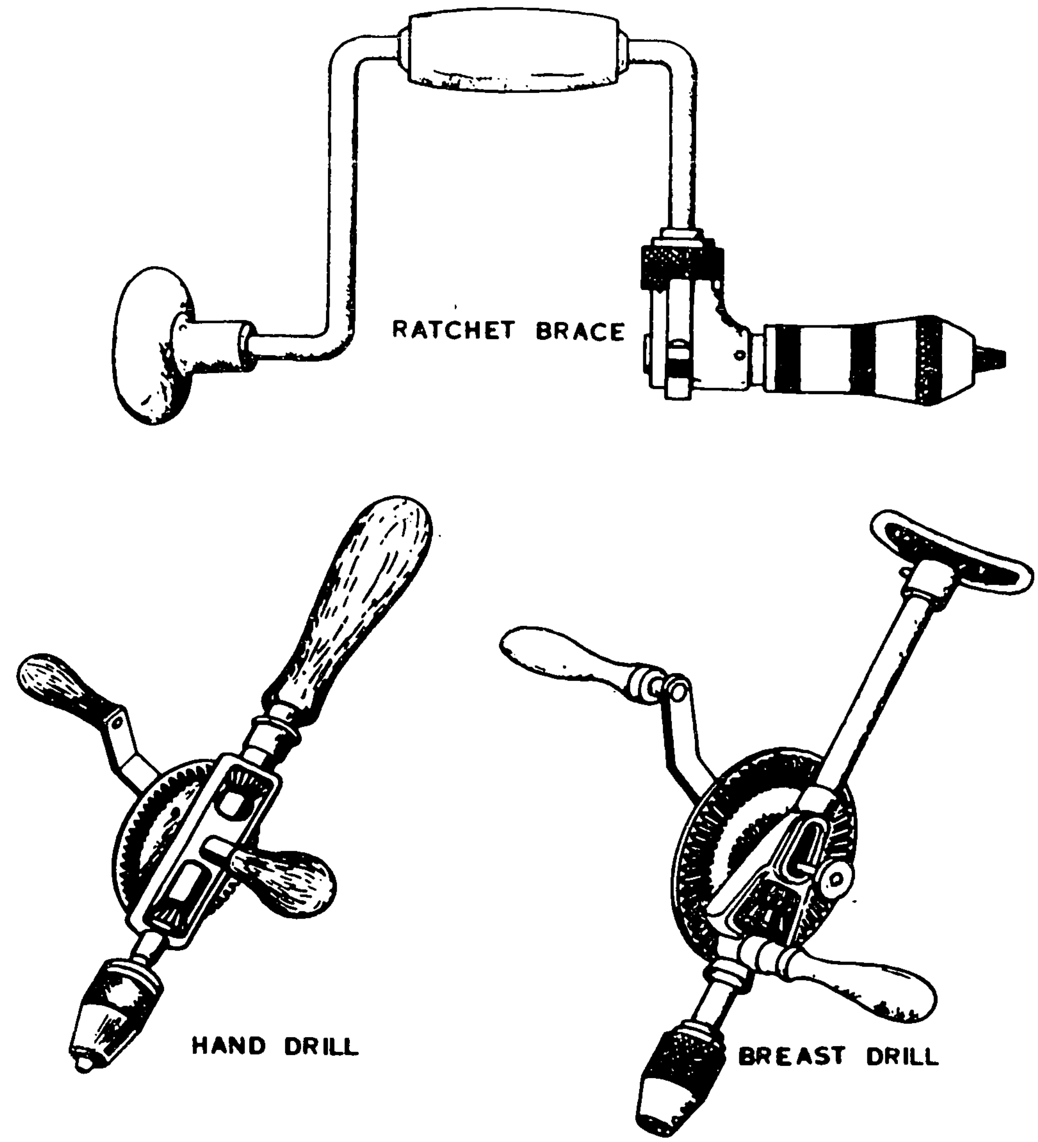


Figure 2–21. Drills.

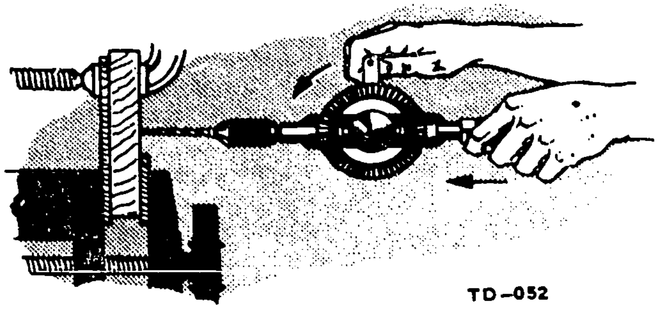


Figure 2-22. Drilling with a hand drill.

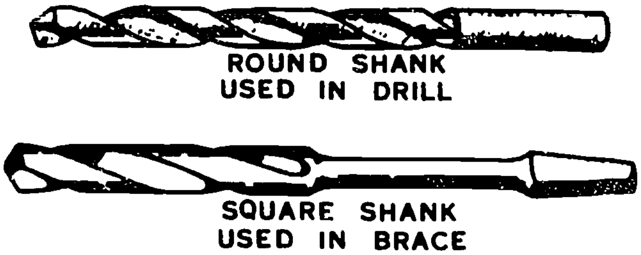


Figure 2-24. Twist bits.

These bits are used to drill holes in wood or metal. You must apply pressure to get the hole started. Always slack off on the pressure as the drill is about to break through. This action often prevents skinned knuckles and helps to prevent the drill from breaking.

*Star bits*. A star bit (fig. 2-25) is used to drill holes in concrete or brick walls and floors for mounting electrical controls or for passage of conduit or cable. Driven by the impact of a ball-peen hammer, the star bit is twisted left and right in the hole as each blow is struck. In hard stone, it is advisable to keep the hole wet to keep the dust down and help clear out the drilled material. The size of the bit used determines the size of the hole being drilled. The smaller sized tools usually are driven by one person. The larger tools require two people. The most common sizes used by the electrician are the 1/4- and 1/2-inch star bits. The star bit, as with other types of bits, requires cleaning after each job and being kept rust-free and well oiled.

**Exercises (219):**

1. Match the descriptive statements in column A to the proper cutting tools in column B by placing the correct letter in the provided blank. Some letters may be used more than once.

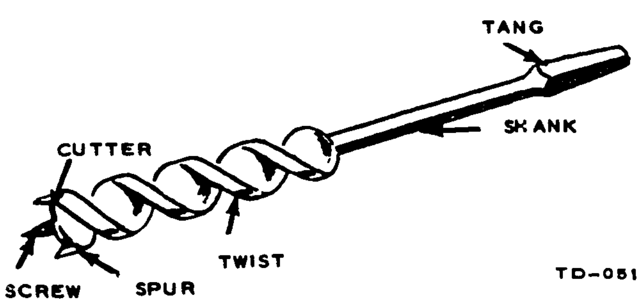


Figure 2-23. Auger bit parts.

*Column A*

_____ (1) Used to cut conduit, tubing, or flat metal.
_____ (2) Used to cut rigid conduit only.
_____ (3) Used to cut wood across the grain.
_____ (4) Used to cut grooves in wood.
_____ (5) Used to enlarge holes in metal.
_____ (6) Used to cut and chip metal.
_____ (7) May be used to strip insulation from wires.
_____ (8) Driven by hand pressure or with a mallet.
_____ (9) Do not break out strip by twisting the tool.
_____ (10) Using the tool on thin-wall conduit flattens the end.
_____ (11) A wrench is used to turn the bolt until a hole is made.
_____ (12) A dull blade for this tool cannot be sharpened.
_____ (13) Requires a hole be drilled or punched before it can be used.
_____ (14) On this tool, a cutting blade angle of 60° to 70° is fine for most light metals.
_____ (15) These tools range in size from 8 to 16 inches.
_____ (16) When using this tool, two or more teeth should always be in contact with the work.
_____ (17) The cutting wheels must be replaced when dull.
_____ (18) A hammer and punch may be used to remove the slug from the die of this tool.
_____ (19) A cutting blade angle of 90° is recommended for cutting hard and tough metal.
_____ (20) Never use a metal hammer to drive this tool.
_____ (21) Should be sharpened on an emery wheel and then honed on an oil stone.
_____ (22) Has a blade that can be used as a screwdriver.
_____ (23) Cuts a 1 11/32-inch hole for 1-inch conduit.
_____ (24) A coarse-toothed blade is used to cut soft metal.

*Column B*

a. Carpenter's saw.
b. Hacksaws.
c. Rigid conduit cutter.
d. Knockout punch.
e. Pocketknife.
f. Cold chisel.
g. Wood chisel.

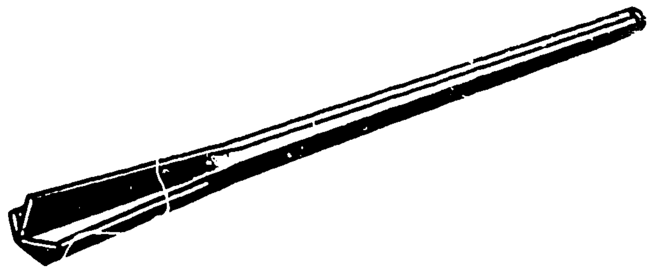

Figure 2–25. Star bit.

2. Match the descriptive statements in column A to the proper boring tool in column B by placing the correct letter in the provided blank.

| *Column A* | *Column B* |
|---|---|
| ______(1) Used to drill holes in concrete or brick walls. | a. Ratchet brace. |
| ______(2) Used for drilling holes in wood only. | b. Hand drill. |
| ______(3) Usually has a round shank. | c. Breast drill. |
| ______(4) Uses bits with a square tang. | d. Auger bit. |
| ______(5) Uses a twist bit and requires only hand pressure. | e. Twist bit. |
| ______(6) Uses a twist bit and allows pressure to be applied with the body. | f. Star bit. |

## 2-2. Special Tools

In addition to the common handtools just covered, there are several special tools used by the electrician to do special tasks. You must know how to select and use these tools to make your job easier. They include fish tapes, rules and tapes, wire gages, fuse pullers, wire strippers, and reaming tools.

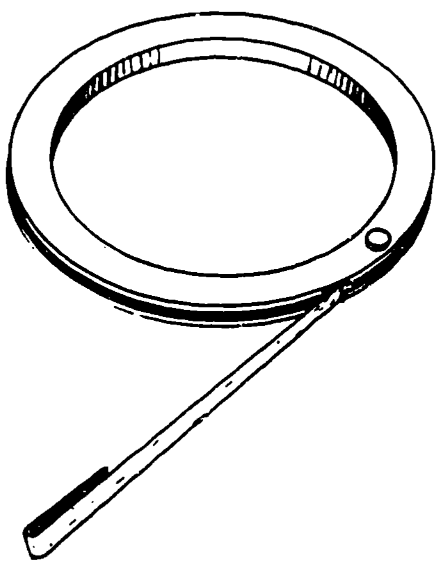

Figure 2–26. Fish tape.

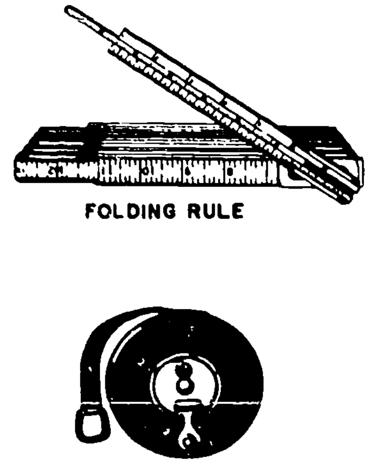


Figure 2–27. Measuring tools.

**220. Name the tools needed to perform given tasks and state how they are used.**

**Fish Tapes.** Fish tapes are made of tempered steel. Most of them are flat and are rolled up in a metal or plastic frame for ease in handling and storage. See figure 2-26 for an illustration of flat-type fish tape. Tapes come in various widths and in coils of 25, 50, 75, 100, and 200 feet. A fish tape is used to pull wire through conduit or other raceways. The fish tape is stiff enough not to bend in normal use but can be pushed or pulled easily through conduit bends. For large conductors, the tape is used to pull a winch line or rope through the conduit first. You then use the winch line or rope to pull the conductors through the length of conduit.

**Rules and Tapes.** Rules and tapes are measuring tools used by an electrician. The 6-foot folding rules and the cloth tape (fig. 2-27) are the most common types. The folding rule is used for measurements of 6 feet or less when doing layout work or roughing in boxes. It is very handy because its hinged sections can be folded and placed in your pocket or tool pouch. To use the rule, hold it in one hand and with the other hand unfold only the sections needed to take the desired measurement. The rule shown in figure 2-27 also has a slide in the end of one section that can be used for taking inside measurements. The cloth tape is used to make long measurements, 10 feet or more, and is made of cloth or linen. The tape is used by placing the metal ring at the end of the tape over a nail at the start of the measurement and walking in the direction to be measured, pulling the tape out of the case. After the measurement is taken, the tape is rewound with the pop-out handle on the side of the case.

Usually the graduations on the rule or tape are in fractions of an inch. A small number printed on the rule near the end tells us the fractions of an inch used on the

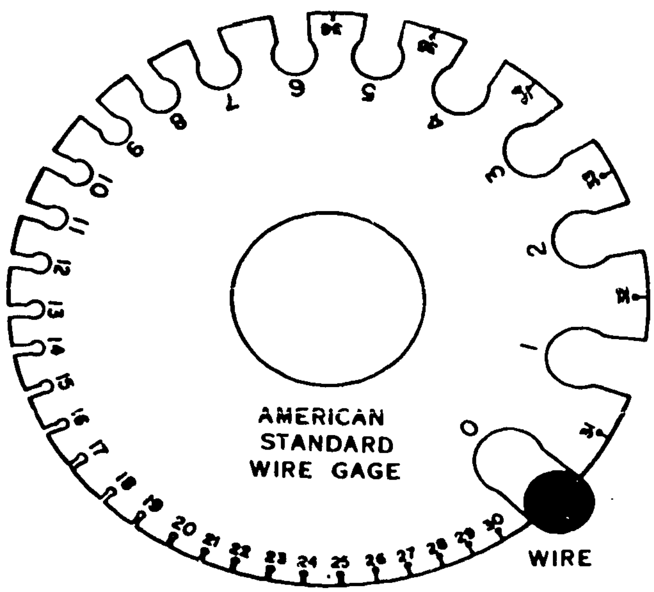


Figure 2-28. Wire gage.

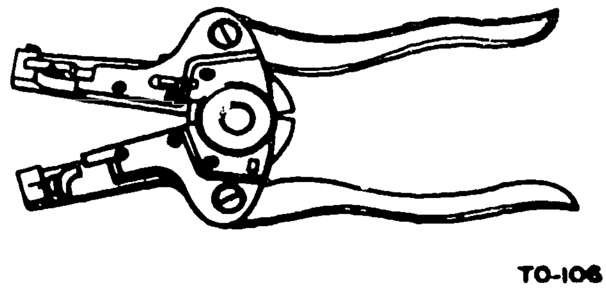


Figure 2-30. Wire stripper.

rule. Thus, the number 8 would indicate that the markings are 1/8 inch apart; the number 16 means 1/16 inch; and 32 and 64 indicate that 1/32- or 1/64-inch graduations are used.

The folding rule must be unfolded carefully to prevent breaking off sections near their joints. Keep the rule clean to prevent the joints from becoming stiff. If the joints become hard to operate, lubricate them with a small drop of light oil or graphite to make the sections easier to unfold. Remove any excess oil with a cloth. Keep the rule folded when not in use. Cloth tapes must be kept clean and dry. Dirt may damage the winding mechanism. If the tape gets wet, unroll it and allow it to dry.

**Wire Gage.** A wire gage is a tool used to measure the diameter of wires. When you read in the code that replacement wires must be of a certain size, you can check them with a wire gage. The gage, shown in figure 2-28, is simply a round, flat metal disc with holes and slots around its circumference. To use it, slide the slots over the wire until you find the slot that fits the wire. The size is etched on the disc next to the slot. The gage shown in figure 2-28 is called the American standard wire gage (AWG) and is the standard gage for electrical wire used in the United States.

**Fuse Puller.** The fuse puller, shown in figure 2-29, is constructed for pulling and replacing both large and small cartridge fuses. It is made of laminated fiber with good insulating qualities. Fuse pullers come in sizes from 5 to 20 inches long. Large pullers contain more laminations and have a larger slot in the jaws to use on bigger fuses. You must always use a fuse puller to pull and replace cartridge fuses to eliminate the danger of electric shock. The puller may be used also to adjust loose fuse clips.

**Wire Stripper.** The wire stripper, shown in figure 2-30, is used to strip the insulation from small-size wires before making splices or attaching the conductor to a terminal screw. The stripper can be used for stripping insulation from various sizes of wire up to No. 12 AWG. When using the stripper, insure that the wire size is not larger than the stripper slots because this would cause damage to the wire. If the wire is stranded, several of the strands will be cut. If the wire is a single strand, it will be nicked and weakened to the point where it will break when twisted even slightly. The wire stripper should be kept clean, and light oil may be used on the moving parts.

**Reamer.** After conduit has been cut to length, the cut end must have the sharp edges removed from the inside to prevent damage to the wire insulation. This procedure is called reaming. Rigid conduit normally is reamed with a tool similar to the drawing in figure 2-31. Notice the square tang on the shank. It normally is used with the ratchet brace described previously. The reaming is complete when the sharp edges and metal burrs have been removed. Do not store the reamer in a position that may cause the cutting edges to become dull. If the reamer is equipped with a ratchet, it should be kept clean and well oiled.

**Exercises (220):**

1. What special tool should you use for pulling conductors (wires) through conduit, and how is it used if the conductors are very large?

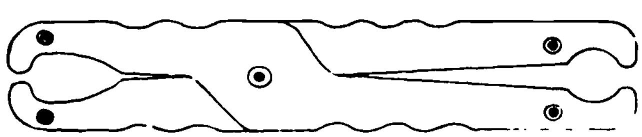

Figure 2-29. Fuse puller.

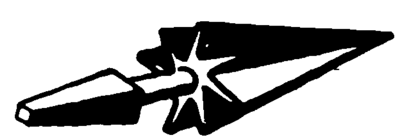

Figure 2-31. Reamer.

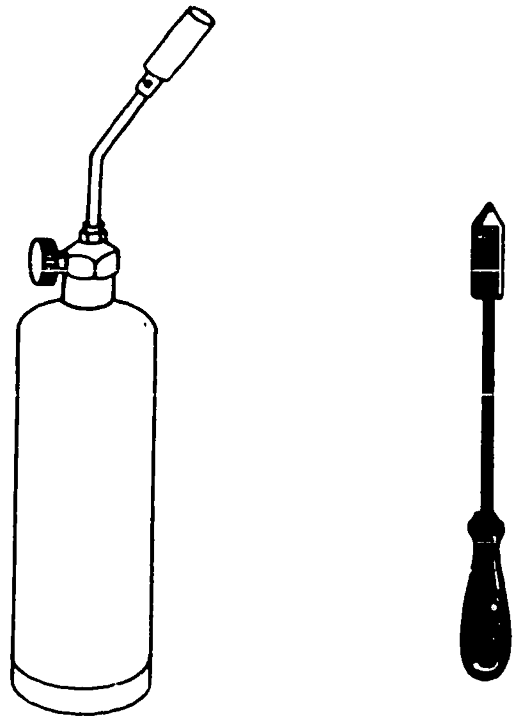


Figure 2–32. Torch and soldering copper.

2. Which measurement tool is used by the electrician for layout or roughing in boxes?

3. How can the folding rule be used for taking inside measurements?

4. What is the purpose of the wire gage?

5. Why should a fuse puller be used in place of something else when replacing fuses?

6. What tool is used to remove the sharp edges from the inside of conduit after it has been cut to length?

7. When using the wire stripper, what precaution should you observe and why?

## 2-3. Soldering Equipment and Soldering

According to the National Electrical Code, a splice must be joined with suitable devices or by soldering. Most of the time you will be able to use the devices made available, such as wire nuts, twist locks, etc. However, there will be times when you will need to solder splices or connections to complete your work.

**221. Identify characteristics of different types of soldering equipment; and cite the function of the heat sink.**

**Soldering Equipment.** Soldering devices are divided into two types: nonelectric and electric. The nonelectric device is used when there is no power source close to the worksite. Two nonelectric devices are the torch and the soldering copper (commonly called a soldering iron), shown in figure 2-32. The torch normally is fueled by a propane bottle that can be changed when it is empty. It can be used for direct soldering of large splices, or it can be used to heat the iron to the desired temperature when soldering smaller splices. The electric gun and electric irons shown in figure 2-33 can be used for soldering when there is a power source close to the worksite. All electric soldering irons and guns are rated in watts. Those with high wattage

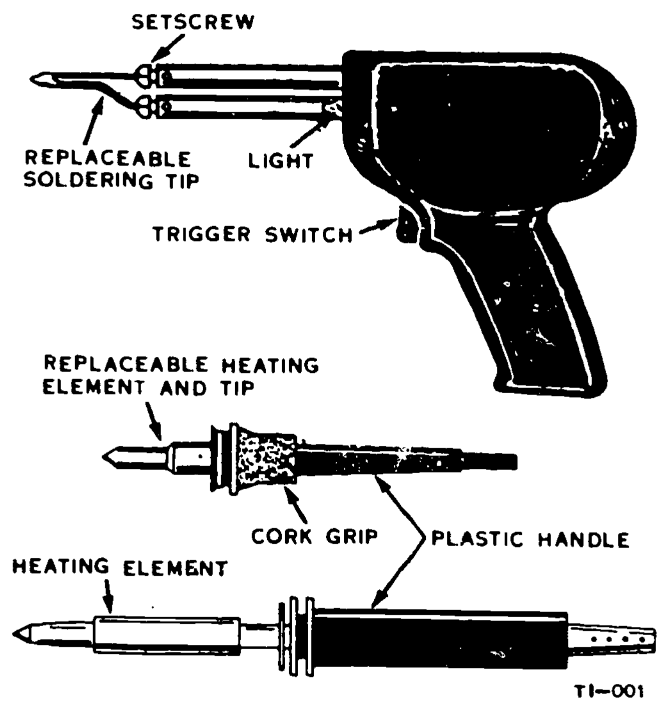


Figure 2–33. Electric soldering gun and irons.

ratings produce more heat. Sinc rge splices require more heat for soldering, a high wattage gun or iron will be needed. Higher wattage devices may be used for smaller splices, but care must be taken to avoid melting the insulation. In some cases a heat sink may be needed to prevent damage to circuit components. The heat sink absorbs heat that might otherwise be absorbed by the component causing it to burn. An example of a heat sink that may be used while soldering is a pair of locking pliers or a spring clamp attached to the work being soldered. The electrical irons and guns have cords of varying lengths and nearly all operate on 120 volts AC.

**Exercises (221):**

1. Name the two types of soldering devices.

2. What fuel is used for the torch?

3. What is another name for the soldering iron?

4. How are electric soldering devices rated?

5. What is the purpose of a heat sink?

**222. Identify materials used in soldering, and specify the proper procedures for using soldering equipment.**

**Soldering.** Soldering is the process of joining metals by adding another metal to bond them together. Electrical work requires solder made with lead and tin in near-equal amounts. Common types of solder used are 60/40 and 50/50. The first number represents the amount of lead and the second number the amount of tin in the solder. To make a good bond, the metal to be joined must be clean, and you must have enough heat to melt the solder. Heat is supplied to the joint to be soldered by one of the devices discussed previously. To clean the joint, a cleaning agent or flux (made of rosin) that removes oxides from the surfaces to be joined is used. Flux may be applied in the form of a paste, or it may be included as the core of the solder. If the flux is in the solder, it is called rosin-core solder. Flux used for soldering sheet metal is made with an acid base. Acid-base flux should never be used for electrical work because it will cause corrosion.

Soldering jobs in electrical work are of three main types: (1) soldering two or more wires together, (2) soldering wires to lugs or terminals, and (3) soldering wires to metal surfaces. No matter which type job you are doing, there are certain steps you must take to have a good soldered splice or connection.

First, the soldering iron or gun must be tinned. To tin the end of the iron or gun, you must first heat it and clean it with flux; then put a thin coat of solder on it. If you have an iron that is burned and pitted, it may need to be filed or brushed before it is tinned. Next, the splice or connection should be twisted or held firmly together. Then prepare the joint for soldering by applying flux. When the metal is heated the flux will boil, cleaning the joint in the process. If rosin-core solder is used, cleaning will take place as you apply the solder.

Now, hold the gun or iron under the joint, if possible, and heat it until the joint, not the iron or gun, will melt the solder. Apply heat until the solder runs freely around the wires of metal being joined. A good soldering job is one in which a thin coat of solder has flowed on all surfaces to be joined. When the solder cools, after you have removed the heat, it should be a dull silver color. If it is a dull white, you have what is known as cold solder joint and you must reheat it. Cold solder joints are caused by not using enough heat. If a cold solder joint is made, it is a waste of time and material to add solder just to make it look better.

**Exercises (222):**

1. What materials are contained in the solder used for electrical work?

2. What do the numbers 60/40 mean as applied to solder?

3. What type of flux is used for cleaning joints in electric soldering?

4. What is the first step in preparing a soldering gun or iron for soldering?

5. After the splice or joint is twisted or held firmly together, what is the next step required to assure a good soldering job?

6. If possible, heat should be applied from which direction?

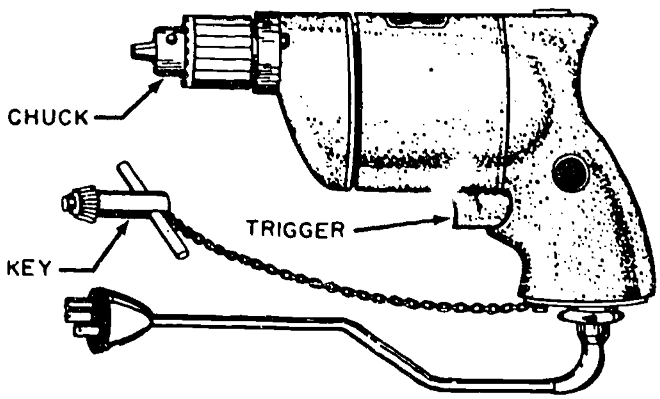

Figure 2–34. Portable electric drill.

7. How do you prevent cold solder joints?

## 2-4. Portable Power Tools

Portable power tools are used to make jobs easier. You can drill holes in wood with a brace and bit, but you can drill the holes much faster and easier with an electric hand drill. For these reasons, you should use the power tools that are available to you whenever possible. In this section, we will cover three of the most common portable power tools used in the electric shop. the electric hand drill, rotary hammer, and saber saw.

**223. Identify characteristics of portable power tools, and cite procedures for their use.**

**Electric Hand Drill.** The most-used portable tool that you will find in the electrical shop is the electric hand drill. With it you can drill holes in almost anything to be found in and around the facilities. The drills are available in various sizes. the size being determined by the largest size drill shank that the chuck will take. For example. a 1/4-inch drill will take all twist bit shanks up to and including 1/4-inch sizes; 3/8-inch size, 3/8-inch bit; 1/2-inch size, 1/2-inch bit; etc. The drills are equipped either with a pistol grip or closed handle (spade grip). The bits are secured in a key-type gear chuck that automatically centers the drill shank. An example of a typical electric hand drill is shown in figure 2-34.

When drilling holes with the electric drill, you must be sure that the bit you are using is suitable for the material to be drilled. In another part of this chapter, you learned that the twist bit could be used to drill wood or metal. Other bits that can be used with the electric hand drill are the spade bit and the masonry bit, shown in figure 2-35.

The spade bit, sometimes called a speed bit, is used only for drilling wood and is available in sizes up to 1½ inches with a 1/4-inch shank. Note that the spade bit does not have a screw tip like the auger bit; therefore, pressure must be applied for starting and drilling. The point is primarily for centering the bit when you start to drill. As the hole is bored, you must reduce the pressure on the drill just before it goes through the wood. If you don't, the bit will splinter the wood and leave a ragged hole.

The masonry bit is used with the electric hand drill for drilling holes in concrete, cinder block, or brick. Often you need to anchor a box or conduit to this type of material. To do this, it is necessary to drill a hole to accommodate a lead anchor or toggle bolt. These bits come in various sizes with shanks of different sizes.

An important thing to remember when using a masonry bit or a twist bit with the electric hand drill is DO NOT overload the drill motor. The best way to do this is to avoid using oversized bits. As an example, if you are drilling metal with a 1/2-inch electric hand drill, do not use a bit that is larger than 1/2 inch.

When drilling metal with a twist bit, center punch the spot to be drilled and drill the hole. Experience will teach you just how hard to push to get the bit to cut a proper sized chip and yet not overload the motor. Watch closely when it seems that the bit is on the point of breaking through. then slacken the pressure so that the bit comes through easily. This will keep it from wedging in the uncut material and sticking, which is apt to break your grip and injure your hand or cause injury to someone else. Occasionally, when drilling wood, a nail is hit while drilling a hole. Here again, the drill will try to twist out of your hand. For these reasons, be sure that you are standing well braced when using the drill.

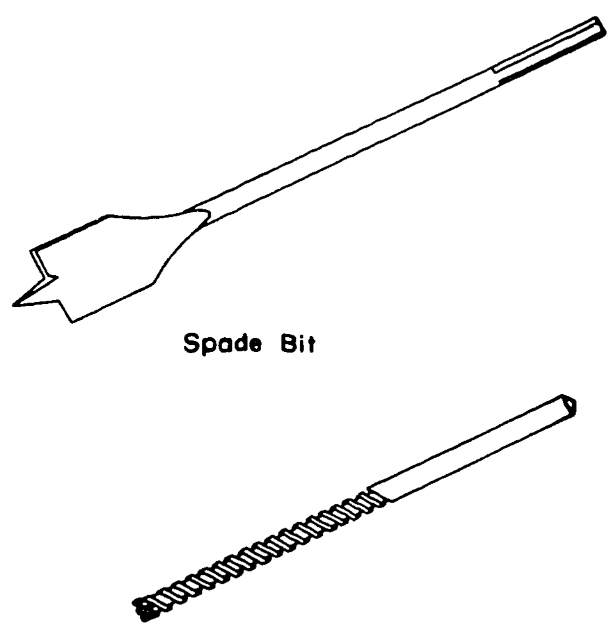

Figure 2–35. Spade and masonry bits.

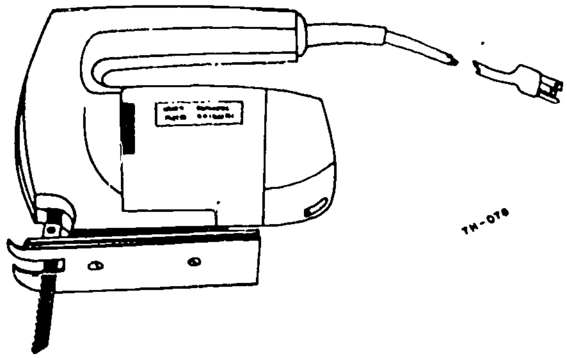

Figure 2-36. Saber saw.

The ventilation holes on the drills should be kept free of dust or lint to prevent overheating of the motor. Continued stalling and overheating will damage the motor to a point where it will become useless. Therefore, do not overload the motor, and keep the chuck clear and well oiled.

**Rotary Hammer.** This portable power tool normally is reserved for heavy construction in concrete or brick. It is designed to drill and hammer the bit simultaneously through the strongest reinforced concrete. The outer shape of the hammer is almost the same as an electric drill, but the hammer is of heavier construction. They are made for drilling holes up to 3 inches in diameter using core bits (hollow center).

When using the rotary hammer, use the same precautions as the electric hand drill, plus, wear eye protection and a mask to protect your nose and throat from dust.

**Saber Saw.** Another common portable power tool used in the electric shop is the saber saw, shown in figure 2-36. Several types of blades are made for the saw to cut different types of material. They can be changed by loosening the set screw that holds the blade in place. The saber saw is used by the electrician to cut openings in finished walls so that outlet boxes or panel boards can be flush mounted. It can also be used to cut notches in studs to make runs of cable and to cut conduit if a metal-cutting blade is used.

To use the saw for cutting openings in finished walls, a pilot hole first must be drilled in the wall. This hole should be inside of the area that is to be cut out. The blade of the saw is then put into the hole with the base plate held firmly against the wall. You may then start to cut the opening required.

When using the saber saw, always apply steady, even pressure and hold the base plate firmly against the work. Forcing the saw will cause stalling and overheating. The saber saw, like the electric drill, has ventilation holes that should be kept clean and free of dust or dirt to prevent overheating.

There is one last thing to remember when cutting or drilling in finished walls or around any electrical circuits that are already installed. That is, check to make sure you do not drill or cut into anything that may be concealed in the wall, including electrical circuits that may be hot.

**Exercises (223):**

From the following statement pertaining to the selection and use of power tools, select those that are true by placing a T in the blank provided or an F for false statements. Correct false statements.

_____ 1. The size of an electric hand drill is determined by the size drill shank its chuck will take.

_____ 2. Bits are secured in an electric drill by a ratchet-type gear chuck.

_____ 3. Bits ordinarily used with the electric drill are the twist bit, spade bit, and masonry bit.

_____ 4. When using a spade bit, pressure does not have to be applied to the drill because it has a screw tip that pulls it into the wood.

_____ 5. To avoid splintering the hole with the spade bit, apply more pressure just before it goes through the wood.

_____ 6. Masonry bits are used with the electric drill for drilling into concrete, cinder block, or brick.

_____ 7. The best way to keep from overloading the electric hand drill is to avoid using oversized bits.

_____ 8. When drilling metal with a twist bit and electric drill, reduce pressure just before breaking through to avoid wedging the bit.

_____ 9. The saber saw can be used for cutting wood or sheetrock only.

_____ 10. When cutting an opening in a finished wall with a saber saw, a pilot hole should first be drilled to use as a starting point.

_____ 11. The base plate of the saber saw should never touch the work because it will mark or scratch the surface.

# Electrical Materials and Devices

TO BE A good electrician, you soon learn that you must be able to select and use the right tool for the job. The same applies to the materials and devices used in your work. If you learn which materials are available to do a job and when to use them, you not only will be able to do a better job, you can do it much faster. In this chapter, you will study materials and devices used in electrical work, such as conductors, boxes and covers, conduit and associated fittings, switches and receptacles, and lighting fixtures.

## 3-1. Conductors

Current flowing through a wire causes heat. The amount of heat varies as the amperage varies. For this reason, various types and sizes of conductors are used in interior wiring to carry differing amperage loads. Also, because conductors are used in many different locations and for different purposes, conductors are made with numerous types of insulation.

In this section the sizes, types, and uses of conductors will be covered so that when it comes time for you to install circuits, you will be familiar with what is available.

**224. Define the terms associated with the use of conductors, and specify the conditions that determine the current-carrying capacity of a conductor.**

**Terminology.** As soon as you start to work as an electrician, you will find that a new language is used. This is true of any trade that has material peculiar to the work that is done. In the electrical trade, two terms that are often used to mean the same thing are "wire" and "conductor." There is nothing wrong with this, but there are times when it is necessary to be more specific. You should learn the following terms and know what each of them means.

*a.* Wire—A thin rod of hard or soft drawn metal. In electrical work, this metal is one that conducts easily, such as copper or aluminum.

*b.* Conductor—As applied to interior wiring, a conductor is a bare or insulated wire or group of wires not insulated from each other and that is suitable for carrying an electrical current.

*c.* Solid conductor—A bare or insulated single wire.

*d.* Stranded conductor—A group of wires twisted together to form a single conductor that may be bare or insulated. (Larger stranded conductors often are called cable.)

*e.* Strand—One wire of a stranded conductor.

*f.* Cable—Two or more solid or stranded conductors insulated from each other that may or may not be contained in a common outer covering.

*g.* Cord—Small stranded flexible cable, usually rubber covered.

**Current Carrying Capacity.** The amount of current a conductor will carry safely depends on four things: the metal used, the size of the wire, the type of insulation, and the location of the conductor. Each of these must be considered when you select the type of conductor to be used for a job.

*Wire materials.* Today wires are made from several materials or combinations of these materials. The most common metals used are copper, copper alloy, aluminum, and copper-clad aluminum. Copper, although the most expensive, is still considered the best. If an aluminum or copper-clad aluminum wire is used in place of a copper wire, it must be one size larger to carry the same current safely. AFM 88–15, *Air Force Design Manual-Criteria and Standards for Air Force Construction*, requires all conductors No. 4 or larger to be copper.

*Wire size.* To work with different size wires, you must know something about the scheme used in wire numbering. Instead of referring to wires by the diameter or area of the wire, numbers have been assigned to represent sizes. The numbers used for electrical wire are called the American wire gage (AWG) numbers. The range of the AWG is from No. 40, the smallest, to No. 4/0, the largest. The number is based on the diameter of the conductor, and a special gage is used to measure the diameter. This gage was covered in Chapter 2 of this volume.

Figure 3-1 shows you the various sizes of wire in the American wire gage. Note that at the bottom of the chart, the last conductor is marked 350 MCM. All conductors larger than No. 4/0 AWG are sized according to the cross-sectional area in circular mils and are designated by MCM (thousand circular mils). A circular mil is the area of a circle one-thousandth of an inch in diameter. The 350 MCM conductor on the chart has a cross sectional area of 350,000 circular mils. Conductors made in MCM sizes range from 250 MCM to 2000 MCM.

Note also on the chart, the larger AWG sizes are listed as stranded conductors. Sizes larger than No. 6 AWG would be very stiff and hard to handle if they were solid. Therefore anything larger than No. 6 AWG—and even some that are smaller—are stranded for flexibility. The most common sizes of conductors you will be working with are from No. 12 AWG through No. 4/0.

AFM 88–15 requires No. 12 AWG to be the smallest

| SIZE | | | NO. OF WIRES | WEIGHT (FEET PER POUND) |
|---|---|---|---|---|
| NUMBER | NATURAL SIZE | DIAMETER (INCHES) | | |
| 40 | TOO SMALL TO SHOW ACCURATELY | .0031 | SOLID | 33,410. |
| 36 | | .0050 | | 13,210. |
| 30 | | .0102 | | 3,287. |
| 24 | | .0201 | | 817.6 |
| 18 | | .0403 | | 203.4 |
| 16 | | .0508 | | 127.9 |
| 14 | | .0640 | | 80.44 |
| 12 | | .0808 | | 50.59 |
| 10 | | .1018 | | 31.82 |
| 8 | | .1284 | SOLID | 20.01 |
| 6 | | .184 | 7 | 12.58 |
| 4 | | .232 | 7 | 7.91 |
| 2 | | .292 | 7 | 4.97 |
| 1 | | .332 | 19 | 3.94 |
| 1/0 | | .373 | 19 | 3.13 |
| 2/0 | | .419 | 19 | 2.48 |
| 3/0 | | .470 | 19 | 1.97 |
| 4/0 | | .528 | 19 | 1.56 |
| 350 MCM | | .681 | 37 | 0.925 |

CEP-13A

Figure 3–1. AWG and MCM conductor chart.

conductor used for general wiring and branch circuits. Smaller sizes, such as No. 14 and No. 16 AWG and below, usually are used for special purposes, such as fixture wiring, appliance controls, signal and alarm circuits, or motor windings. You must remember, the size of a conductor is determined by the diameter or cross-sectional area of the wire, which does not include the insulation.

*Insulation.* The type of insulation needed for a conductor is based primarily on where it is going to be used. For example, you should not use a rubber- or plastic-insulated wire in a place where it would be subjected to very high temperatures. On the other hand, you should not install an asbestos-insulated wire where it might get wet. The types of insulation and where they can be used are covered in the *National Electrical Code* (NEC) book. The code also requires manufacturers of wire and cables to identify their product properly. They must show the size of wire, the type of insulation, the maximum working voltage, and the manufacturer's name or trademark. This information is placed on the outer surface of the insulation. You can learn a great deal about the wire or cable by reading the markings. Some of the common letters used to indicate a type of insulation or a characteristic are as follows:

- A–Asbestos.
- H–Heat resistant.
- R–Rubber.
- T–Thermoplastic.
- V–Varnished cambric.
- W–Moisture resistant.

These letters often are used in combination to indicate an insulation type. For example:

- TW–Moisture-resistant thermoplastic. Used in dry or wet locations.
- RHW–Heat- and moisture-resistant rubber. Used in dry or wet locations.

AFM 88–15 requires that all conductors No. 6 AWG or larger must have a minimum of heat resistant insulation plus one or more of the insulations listed above.

*Location.* As mentioned before, the location where the conductor is to be installed also has an effect on the current-carrying capacity. A conductor used in free air will carry safely more current than the same conductor installed along with other conductors in conduit or cable. The reason is that the conductor in free air is able to get rid of the heat caused by current flow much faster than if it were in conduit or cable. The number of conductors installed in conduit also has an effect on the current-carrying capacity. The more conductors there are, the lower the safe current-carrying capacity. To determine the amount of current a specific size and type of conductor used in a certain location can carry, you must refer to the *National Electrical Code*. We will discuss current carrying capacity in detail in Chapter 5.

**Exercises (224):**

1. Define wire.

2. Define conductor.

3. What is the difference between a solid and a stranded conductor?

4. Of the materials used for conductors today, which is the best?

5. What is the size range of the American wire gage?

6. Which is the larger conductor, a No. 2 AWG or a No. 20 AWG?

7. How are conductors larger than No. 4/0 AWG sized and numbered?

8. Why are larger conductors stranded?

9. What do the following letters mean when used for marking insulation types?

   a. TA.

   b. RH.

   c. THW.

10. Why do conductors in conduit or cable have a smaller ampacity rating than the same conductors run in free air?

## 3-2. Boxes and Covers

Boxes and covers come in a variety of types and sizes that you will use eventually when installing an electrical system. This section covers the purpose, types, and uses of a number of these boxes and covers.

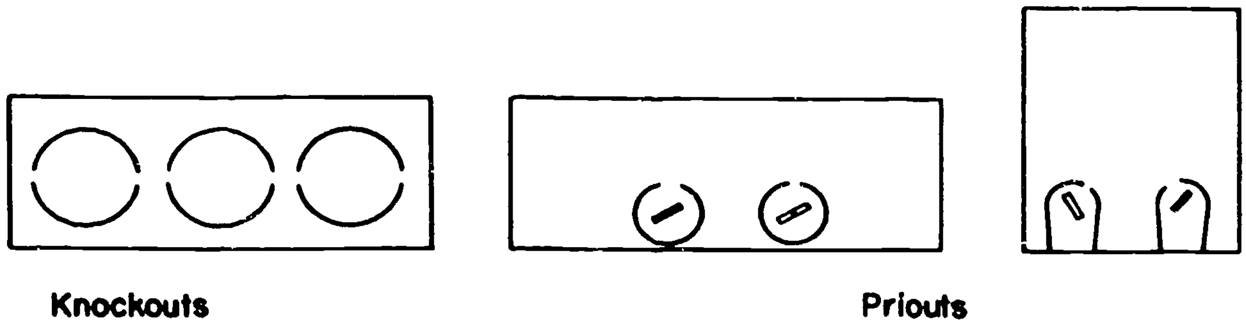


Figure 3–2. Box knockouts and priouts.

**225. Specify the purpose, types, and uses of outlet and junction boxes required in interior electrical systems.**

**Purpose.** The *National Electrical Code* requires that all connections to electrical devices or lighting fixtures and all connections between conductors in interior wiring systems be inclosed. The main purpose of this requirement is to reduce the possibility of fire that could start easily from a short circuit or a poor connection near combustible material. The required inclosures also provide physical protection for wire terminals, splices, and electrical devices. In addition, people are protected from accidental shock, burns, or possible electrocution that could occur if attachment terminals were not inclosed.

Outlet boxes and junction boxes are used to provide the required inclosures. Switches and receptacle outlets are installed in outlet boxes. Lighting fixtures are attached to outlet boxes that have been mounted securely to the building structure. Conductor connections and splices are inclosed in junction boxes. The larger junction boxes that have terminals for making conductor connections are limited to such use. However, smaller junction boxes normally used for conductor splices and outlet boxes often are used interchangeably. Splices are quite common in boxes that contain electrical devices. On the other hand, boxes usually used for splices can be adapted to electrical devices or lighting fixtures by use of specialized box covers.

**Construction.** Boxes come in various shapes and sizes. They can be classified into two types: those used for concealed wiring and those used for exposed or surface-mounted wiring. Surface-mounted boxes are known as utility boxes but often are referred to as handy boxes. Boxes may be made of metal or nonmetallic (NM) insulating material. Metal boxes are made from sheet steel, malleable iron, or cast metals, such as aluminum, brass, or bronze. Metal boxes and fittings not made from corrosion resistant materials must be galvanized, enameled, or otherwise coated to prevent corrosion. Enamel-protected boxes are not used in damp or wet locations. Metal boxes can be used with any type of wiring. However, use of nonmetallic boxes is limited to nonmetallic wiring methods, such as nonmetallic-sheathed cable or rigid nonmetallic conduit (plastic pipe, PVC).

**Description and Use.** Boxes may be round, octagonal, square, or rectangular in shape. All boxes have an open side, which is closed after installation by an electrical device, lighting fixture, or cover plate. Boxes are provided with knockouts, priouts, or a combination of the two.

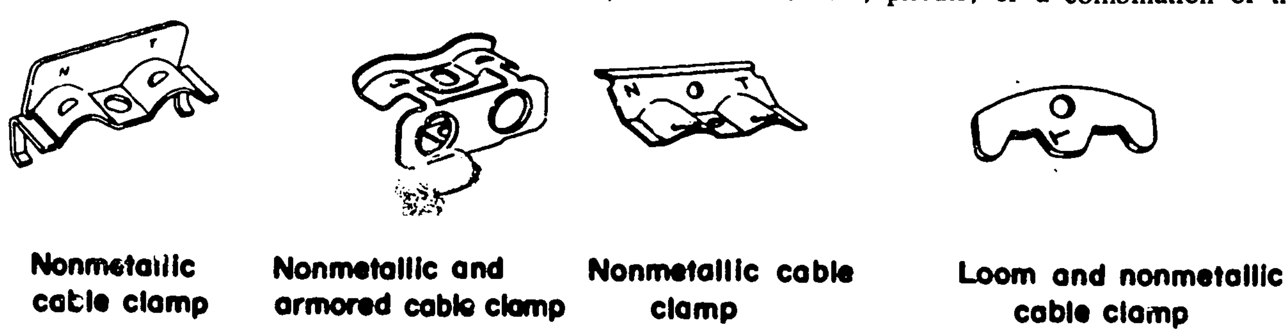


Figure 3–3. Box clamps.

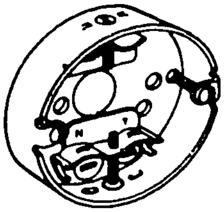

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Figure 3–4. Round outlet box.

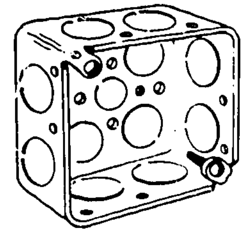

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Figure 3–6. Square box.

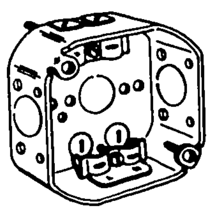
Knockouts are prepunched disks that can be knocked out easily to permit conduit or cable connectors to be installed. There may be several sizes of knockouts on a box to accommodate more than one size of conduit. Priouts are prepunched slotted pieces that are pried out by inserting a screwdriver blade in the slot and then twisting and bending. Priouts are provided in boxes that have built-in clamps to secure the cable. Figure 3-2 shows examples of both knockouts and priouts. Figure 3-3 illustrates four typical box clamps.

*Round boxes*. Round outlet boxes, as shown in figure 3-4, usually are installed in the ceiling. They are used as lighting outlets and to support lighting fixtures. Such boxes often are referred to as ceiling boxes or ceiling pans. Round boxes are 3½ or 4 inches in diameter. Most metal boxes are only 1/2 or 3/4 inch in depth. Nonmetallic boxes range up to 3 inches in depth. When shallow boxes (1/2 of 3/4 inch) are used, wire entrances are located in the bottom of the box. The box not only includes the circuit and the fixture wires, and their connections, but it also supports the fixture. Heavy lighting fixtures, over 50 pounds, need added support. This support is provided by a fixture stud. Boxes are available with fixture studs installed or a separate stud, with or without a bar hanger, can be mounted through the center knockout. Round boxes cannot be used where conduit or cable connectors that require the use of locknuts or bushings are to be connected to the side, because there are no holes in the sides of these boxes.

*Octagonal boxes*. Octagonal boxes are not true octagons, but are more like squares with rounded off corners, as you can see in figure 3-5. These boxes are used mainly for lighting outlets. Generally, they are easier to use than round boxes since any type of wiring, including conduit, can be brought into the box from the sides, as well as from the back. Most octagonal boxes are either 3½ or 4 inches across and range in depth from 1½ inches to 2 inches. There are some specially hung ceiling boxes that are 3½ inches deep. Octagonal concrete boxes are as deep as 6 inches. Octagonal boxes have knockouts, priouts, cable clamps, and threaded holes for mounting lighting fixtures or electrical devices, and may have fixture studs added.

*Square boxes*. Square boxes (fig. 3-6) are, as their name implies, square, except that the corners of many of them are smoothly rounded. The most common sizes of square boxes are 4 to 4 inches across and from 1¼ to 2 inches in depth. Other sizes of boxes are available. The size of box needed for a specific location is determined by the size and number of conductors in the box. These limitations are governed by the NEC and will be discussed later. Square boxes are used mostly as junction and pull boxes. A pull box allows conductors to be pulled through the conduit to an intermediate point and, eventually, to the point of use, without having to be cut and spliced. Square boxes are also used with adapter plates to mount electrical devices. This is most likely to be done when conduit is to enter and leave the box on the same side or when added space is needed because of the number and size of conductors involved. Another use for square boxes is to mount special purpose outlets, such as the type used for an electric range.

*Device boxes*. Device boxes or switchboxes (fig. 3-7) are rectangular in shape. These boxes are used for mounting



CEQ-093

Figure 3–5. Octagonal box.

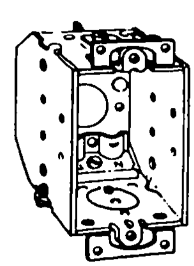


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Figure 3–7. Device box.

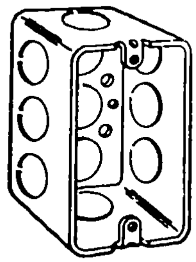



Figure 3–8. Utility box.

single toggle switches and single or duplex receptacle outlets. If you look at the lower left side of the figure, you can see a screw at the side of the box. Removal of this screw allows the side of the box to be removed by unhooking the interlocking tabs at the upper left of the box. By removing the right side of a matching box, the two boxes can be fastened together with the screws. This procedure is known as ganging and is done to permit more than one switch, receptacle, or a combination of the two to be mounted side by side with a single cover plate. (Not all devices or switchboxes can be ganged.) Some switchboxes for use with nonmetallic cable have the bottom inside corners beveled, but in most cases, the beveled and square cornered boxes can be used interchangeably with NM cable. Switchboxes are 3 x 2 inches and range in depth from 1½ to 3½ inches.

*Utility boxes*. Utility boxes or handy boxes are rectangular in shape, as shown in figure 3-8. These boxes were designed mainly to permit surface installation of switches and receptacle outlets with exposed metal conduit. Because they are made only with conduit knockouts, nonmetallic cable connectors are required if wiring is to be done with nonmetallic cable. Handy boxes also may be used with surface metal raceway, provided the proper type of connector is used. These boxes are used for such other purposes as junction boxes and switch or receptacle outlet boxes in concealed wiring. On the other hand, square boxes sometimes are used for surface wiring, especially where two switches or duplex outlets are to be installed at the same spot. Octagonal boxes make fairly neat looking junction boxes for surface wiring. Actually, most of the boxes discussed are installed at various times for other than their primary purpose. The round box or ceiling pan is the least versatile when an alternate use of a box is being considered.

*Extension rings*. Extension rings are used to increase the depth of octagonal and square boxes. They are similar in appearance to the boxes themselves except that instead of having a closed back, a narrow flange provides a seat for mounting the extension to a box. Figure 3-9 shows octagonal, square, and handy box extension rings. Extension rings for octagonal and square boxes are 1½ inches or 2 inches deep. Extension rings for these boxes increase box capacity, bring the edge of a box out flush with the wall surface when the box has been mounted too deep, and extend the edge of an old box beyond the surface of a wall to permit the addition of surface wiring. Handy box extensions are either 1½ or 1 inches deep and are used primarily with an existing flush outlet to permit the addition of surface wiring. Another form of extension ring, although technically not classified as such, is a ring designed to allow switches and receptacle outlets to be mounted flush with existing outlet boxes when a wall is resurfaced. The new wall surface might consist of the attachment of sheetrock or paneling directly to the old surface or the addition of furring strips between the old and new surface. Figure 3-10 shows how these extension rings are used to permit the flush-mounting of devices after a new wall surface is added. The ring is held in place by long screws passing through the mounting holes in the device and the unthreaded holes in the ring's ears and screwed into the device-mounting holes on the box. These rings allow the flush mounting of switches and receptacles up to an inch away from the original wall surface.

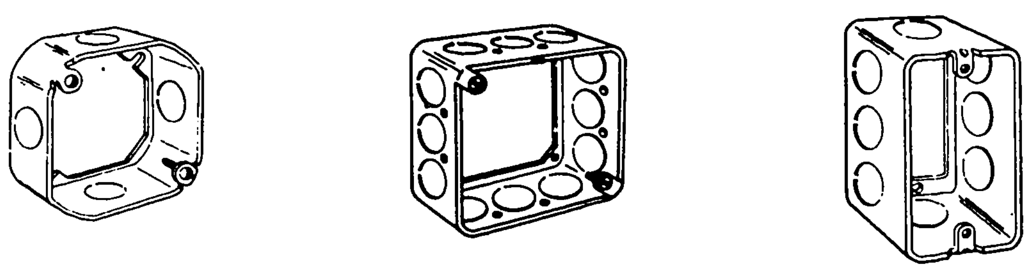



Figure 3–9. Extension rings.

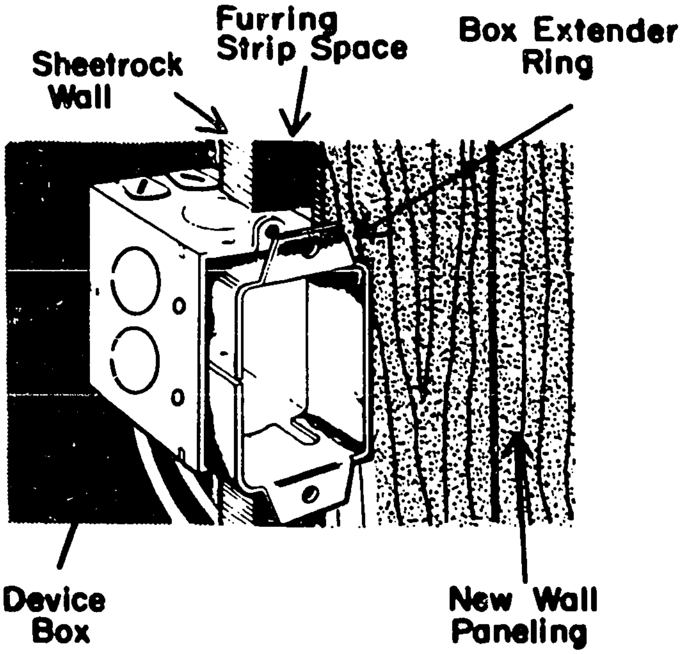



Figure 3–10. Box extender ring.

**Exercises (225):**

1. What are three reasons for electrical connections to be inclosed?

2. What is used to provide the required inclosures for electrical connections?

3. What is the difference between an outlet box and a junction box?

4. Mark the following statements true (T) or false (F) in the space provided.

   _____a. Large junction boxes are not used for outlets.
   _____b. Conductors must be jointed together in a junction box.
   _____c. A small junction box can be used to mount a duplex receptacle.
   _____d. Splices in boxes with electrical devices are hazardous.
   _____e. Lighting fixtures must be installed on an outlet box.

5. What is another name for utility boxes?

6. Name two types of materials used to make boxes.

7. How is corrosion prevented on boxes not made of corrosion-resistant material?

8. Where may nonmetallic boxes be used?

9. Describe a box knockout and state its purpose.

10. Describe a priout and explain when priouts are put in boxes.

11. Indicate the type of box that would normally be first choice for the purposes listed in column A by inserting the appropriate letter in the space provided. Selections in column B may be used once, more than once, or not at all.

| *Column A* | *Column B* |
|---|---|
| _____(1) Surface-mounted receptacle. | a. Round box. |
| _____(2) Receptacle outlet. | b. Octagonal box. |
| _____(3) Surface-mounted junction box. | c. Square box. |
| _____(4) Ceiling light. | d. Device box. |
| _____(5) Wall-mounted light. | e. Utility box. |
| _____(6) Conductor splices or pull boxes. | |
| _____(7) Single-toggle switch. | |
| _____(8) Two single-toggle switches. | |

12. How are heavy light fixtures supported?

13. When installing ceiling lights with conduit, what is the advantage of using octagonal boxes instead of round boxes?

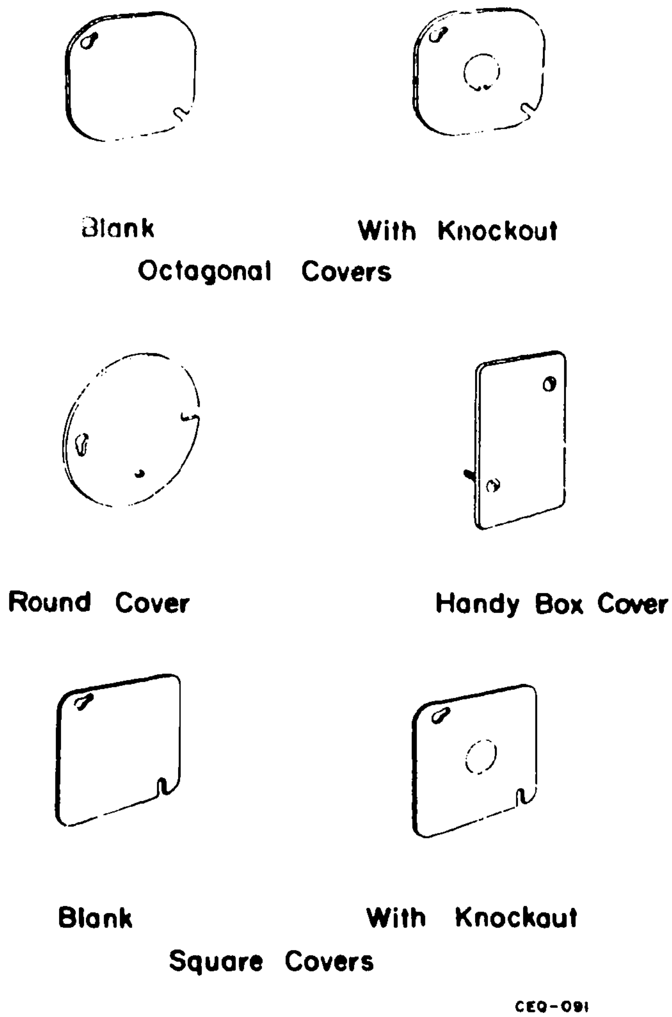



Figure 3-11. Flat covers.

14. What is a pull box?

15. When wiring with conduit, what type of box should be used when conduit is to enter and leave the box on the same side?

16. What is meant by ganging boxes together and when is it done?

17. What two uses can be made of utility boxes other than for surface-mounted switches or receptacles?

18. When considering the installation of a box for other than its primary purpose, which one would you probably not consider?

19. Describe an extension ring.

20. What are three uses for extension rings?

21. How may installed switch boxes be used when a room is repanelled using 3/4-inch furring strips and 1/4-inch plywood?

**?26. Identify box covers in terms of their purposes and design characteristics.**

**Box Covers.** A junction box or an outlet box is not complete unless it has a cover to close it. The cover provides both protection and a neat appearance. There are several designs of box covers—round, square, rectangular, flat, raised, device mounts, and exterior covers. Covers may be made from metal, insulating material, or plastic.

Flat covers may be used for several purposes. Blank ones serve to close the box and protect the wiring inside. Some flat covers have knockouts to permit connection of conduit, armored cable, or nonmetallic cable. Others have openings designed for the mounting of certain electrical devices. Round and octagonal covers can be used with either round or octagonal boxes. Square covers fit square boxes and rectangular covers fit rectangular boxes. Several flat covers are shown in figure 3-11.

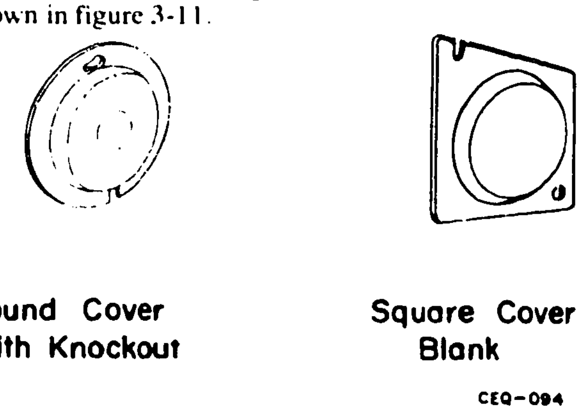



Figure 3-12. Raised covers.

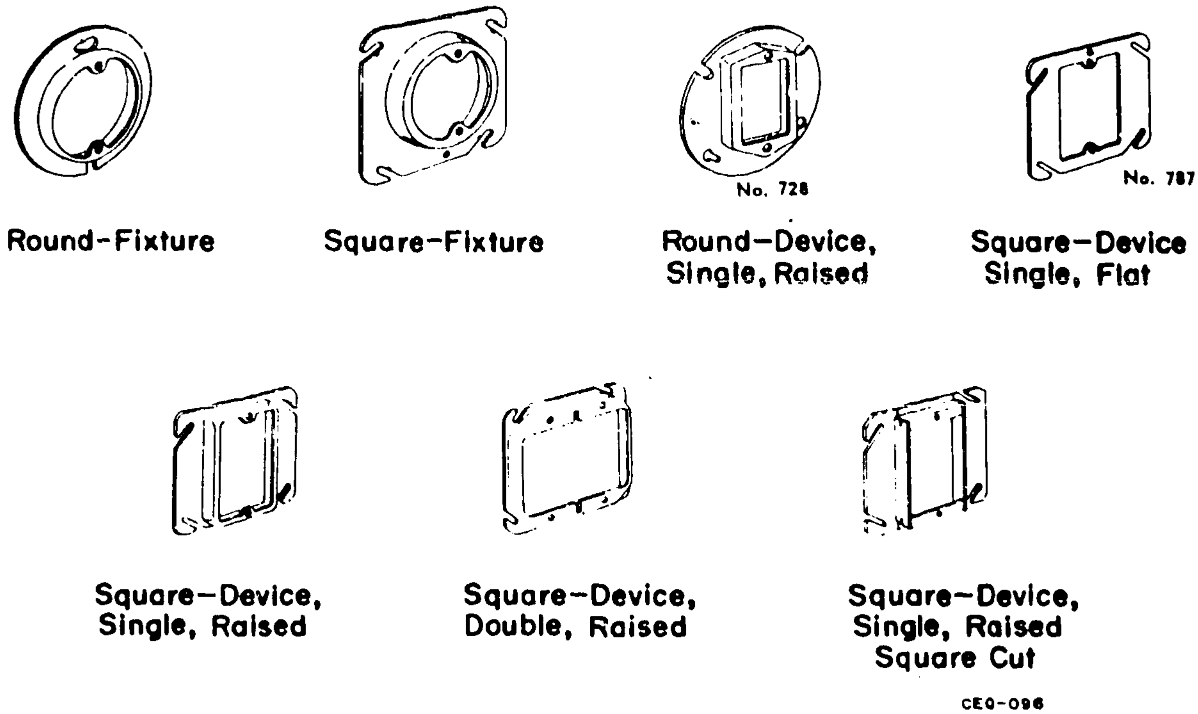



Figure 3-13. Device covers.

Raised covers take several forms. Some of them are used to provide added interior space in the box, as well as to close it. Figure 3-12 illustrates this type of cover. These covers are usually 5/8 of an inch deep and increase the cubic capacity of a box by about 3.8 cubic inches. There is another group of covers commonly referred to as device covers. They are made to allow the mounting of electrical devices or round, octagonal, and square boxes. Device covers may be either flat or raised. The location of the box determines which type to be used. Raised device covers range in depth from 1/4 inch to 1½ inches. The depth is based on the thickness of material used to construct the wall materials; that is, dry-wall or sheetrock, plaster, tile, or wood. Figure 3-13 shows a number of device covers. The two at the upper left are electrical fixture mounts rather than device mounts. The one at the lower right is a square-cut cover designed to be used with a tile wall.

Another type of cover is used to cover the box after one or more electrical devices have been installed. Those covers are used to provide a finished appearance. Exterior covers fall into two major groups—those for surface wiring and those for concealed wiring. The covers for exposed wiring also are of two general types—flat covers and raised covers. Flat covers for surface-wiring are used for finishing when extra space is not needed in the box. Examples of flat covers for octagonal and handy boxes are shown at the top of figure 3-14. When extra space is required in the box, raised covers are installed to provide an extra 7.3 cubic inches of space. The center of figure 3-14 shows some raised covers. Covers for concealed wiring fit flush with the surface in which the box is mounted with some typical examples shown at the bottom of figure 3-14.

Exercises (226):

Identify each of the following statements about box covers as true (T) or false (F) in the space provided.

_____ 1. Box covers are used to provide protection, as well as to give work a finished appearance.

_____ 2. Round and square box covers are metal but rectangular ones are plastic.

_____ 3. Flat, blank box covers are used for protection of the inclosed wiring.

_____ 4. One purpose of a raised cover is to increase box space.

_____ 5. Device covers are needed when electrical devices are installed in switchboxes where there is a requirement to adapt to a different configuration.

_____ 6. The depth of a raised device cover is based on the thickness of the wall-surfacing material.

_____ 7. A square-cut device cover is required for a tiled wall.

_____ 8. Boxes used for surface-wiring undersize require raised covers to meet space requirements.

_____ 9. Exterior device covers can be used interchangeably for either surface or concealed wiring.

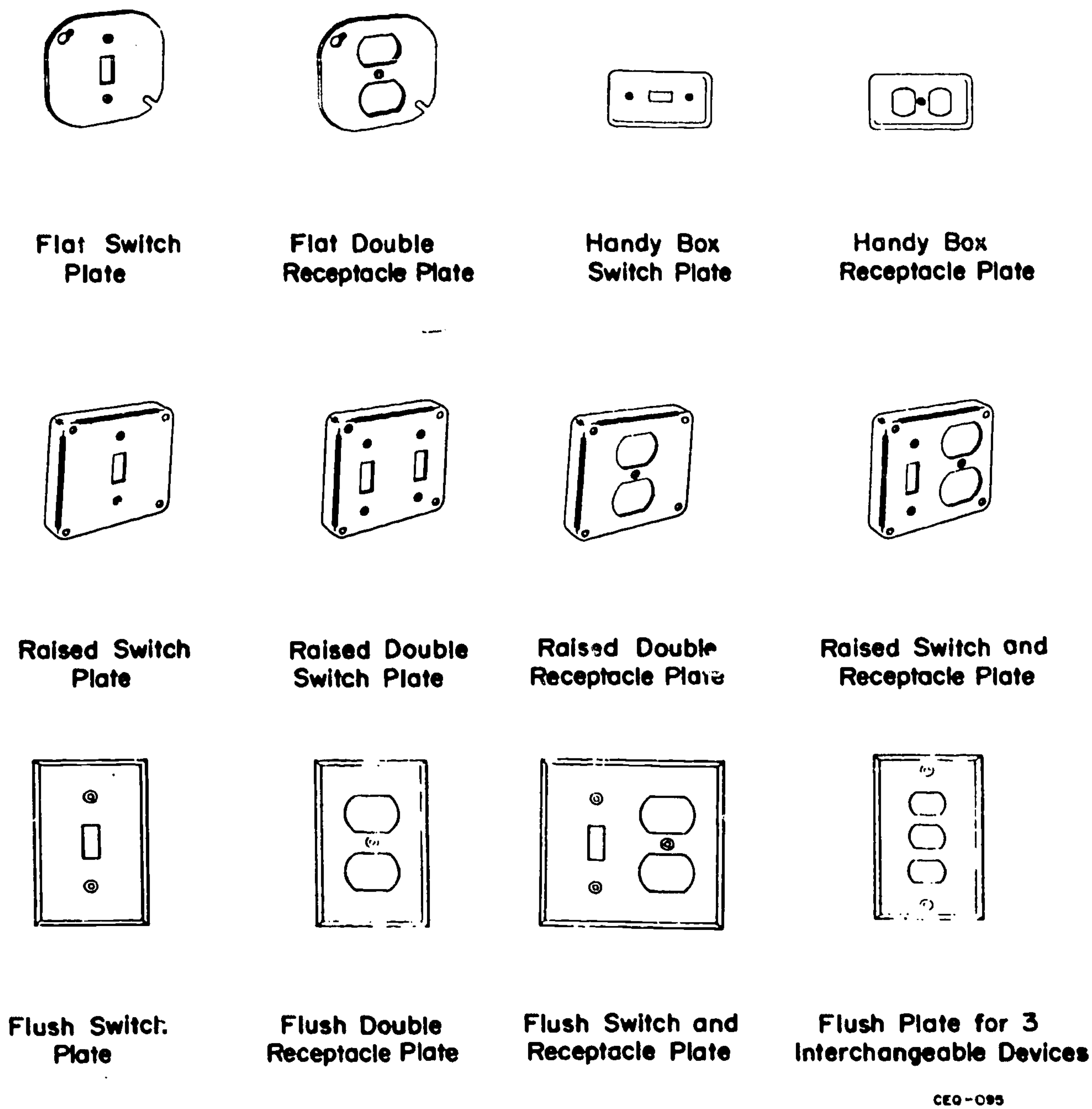



Figure 3–14. Flat, raised, and flush device plates.

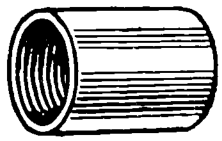


Figure 3-15. Threaded coupling.

## 3-3. Conduit and Fittings

One of the methods used for wiring circuits in buildings is by installing conductors in conduit. In this section, we will cover the types of conduit and the fittings used with each type.

**227. Identify conduit and conduit fittings in terms of their design characteristics and applications.**

**Conduit.** Conduit is a term used in the electrical field to describe certain types of raceways. Raceway, as defined in the *National Electrical Code*, is basically a channel designed expressly for holding wires, cables, or bus bars (a copper bar often used in place of wire or cable). This definition includes all types of conduit. Conduit, the fittings used for installation, and the boxes discussed previously make up what is known as a conduit wiring system. These systems provide good physical protection and can be installed in many places where other types of systems cannot.

*Rigid metal conduit.* Rigid metal conduit is very similar to the pipe used by plumbers. The main difference is that conduit is finished smooth on the inside. The metals used to make rigid conduit are steel or aluminum. There are two types of steel (ferrous), rigid metal conduit: enamel-coated and galvanized. The enamel-coated conduit can be used only indoors and in places not subject to severe corrosive influences. The galvanized conduit can be used in any location, including in concrete or underground. Rigid metal conduit is made in sizes ranging from 1/2 inch to 6 inches. The size is determined by the inside diameter of the pipe, as is the case with all types of electrical conduit. It comes in lengths or sticks of 10 feet with tapered threads cut on either end. Threaded sleeve couplings, as shown in figure 3-15, are used to connect two pieces of rigid conduit. Where the conduit is connected to boxes, you must use locknuts and bushings. For circuits of less than 250 volts, you may use one locknut and a bushing to connect the conduit to a box. This installation is shown in figure 3-16. For circuits above 250 volts, two locknuts and a bushing are required. One locknut is placed on the outside of the box; the other is placed on the inside. The two locknuts insure better grounding of all the conduit and boxes in the system. The bushing protects the circuit wires from abrasion against the end of the conduit. All couplings and connections in rigid conduit systems must be made wrench tight. The number of circuit wires that may be installed in each size of conduit is governed by the *National Electrical Code*.

*Rigid nonmetallic conduit.* Rigid nonmetallic conduits constructed of a nonmetallic material that must be resistant to moisture and chemical atmospheres. For use aboveground, it must also be flame-retardant, resistant to impact and crushing, resistant to distortion from heat, and resistant to low temperature and effects of sunlight. This conduit is normally made of polyvinyl chloride (PVC) and is also similar to the plastic pipe used by plumbers. Connections and couplings are made with threadless fittings that are glued together with a special glue. The smallest size rigid nonmetallic conduit is 1/2 inch. This type of conduit offers good physical protection to the conductor, is easy to install, and can be used in many of the same locations as rigid metal conduit.

*Electrical metallic tubing (EMT).* Electrical metallic tubing is also known as thin-wall conduit. It is the most popular conduit for interior wiring systems. However, unlike rigid conduit, there are certain restrictions for its use. It cannot be used in a hazardous location or where it might be subjected to severe physical damage.

Thin-wall conduit is usually made of galvanized steel. Its walls are much thinner than those of rigid conduit. Because of its thin walls, it cannot be threaded. Instead of threaded couplings and connections, compression-type, crimp-type, or setscrew-type fittings are used with thin-wall conduit. Figure 3-17 shows a compression-type, thin-wall

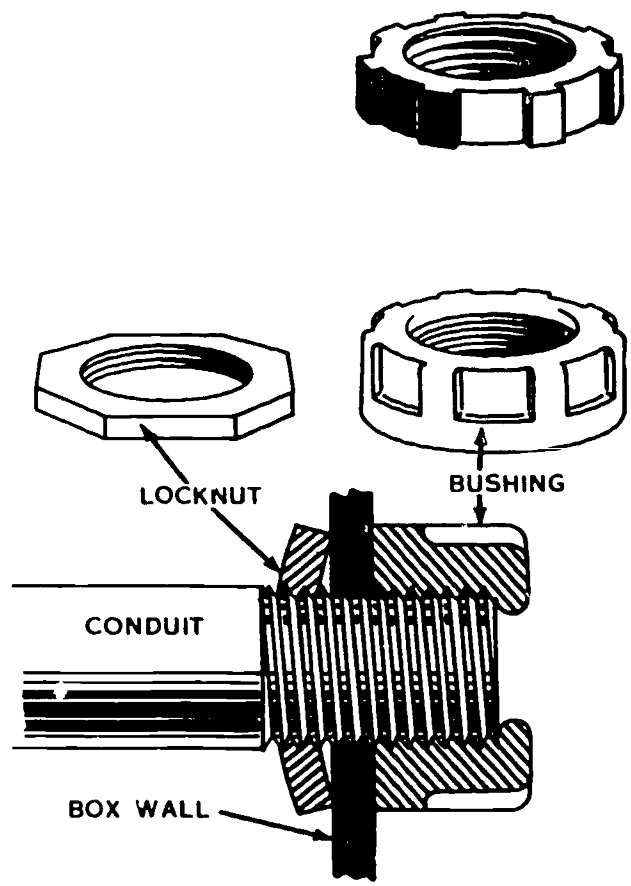
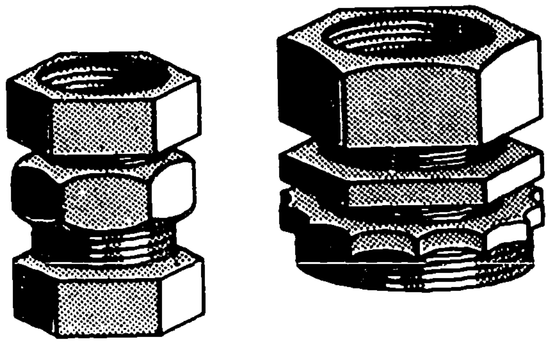


Figure 3-16. Rigid conduit connection.



COUPLING CONNECTOR

Figure 3–17. Thin-wall conduit fittings.

coupling and connector. The coupling is used to join two lengths of conduit together. The connector is used to connect conduit to a box.

Thin-wall conduit is available in sizes from 1/2 inch through 4 inches, in lengths of 10 feet. Various types of fittings and adapters are available for joining thin-wall conduit to rigid and flexible conduit.

*Intermediate metal conduit (IMC).* This type of conduit is a new product designed to be used as an alternate to rigid metal conduit. It can be used in the same locations as rigid metal conduit and some of the same fittings may be used for installation. It is made in sizes ranging from 1/2 inch to 4 inches. The main difference between intermediate and rigid is in the weight. Intermediate has a smaller conduit wall thickness, therefore, it is lighter and somewhat easier to bend. You will learn more about bending and installing thin-wall, rigid conduit, and IMC later in this volume.

*Flexible conduit.* Flexible conduit (flex) comes in three types. They are flexible metal tubing, flexible metal conduit, and liquidtight flexible metal conduit. The flexible metal tubing is a circular, flexible, metallic, liquidtight (without jacket) type of raceway used where it will not be subject to physical damage, such as above a suspended ceiling for connecting light fixtures. It comes in 1/2- and 3/4-inch electrical trade sizes and cannot be used in sections more than 6 feet in length. The use of flexible metal tubing is limited to branch circuits in dry locations with 1000 volts maximum circuit potential.

Flexible metal conduit is similar to flexible metal tubing. The main difference is that it is stronger and will withstand more physical abuse. Its use is not limited to 6-foot lengths and the maximum size is not limited as it is with flexible tubing.

Liquidtight flexible metal conduit is actually flexible metal tubing with an outer liquidtight, nonmetallic, sunlight-resistant jacket. This conduit can be used in exposed and concealed work, in wet or dry locations, and in some hazardous locations where it is approved specifically by the NEC. It cannot be used where it might be subject to physical damage or where the ambient or conductor temperature will produce an operating temperature in excess of that for which the outer jacket is approved.

In general, flexible conduit is used to connect equipment that may be subject to vibration, such as motors. It may also be used for extending circuits where bending rigid or EMT is too difficult and physical protection is needed for the conductors. Each type of flex must be used with fittings approved for the purpose of coupling and connecting that particular type. Figure 3-18 shows some examples of flexible metal conduit connectors. Figure 3-19 shows a liquidtight flex connector. With certain exceptions, as outlined in the NEC, the minimum size flexible conduit that can be used is 1/2 inch. The maximum size depends on the type. Flexible metallic tubing is limited to 3/4 inch and liquidtight flex is limited to 4 inches. Flexible metal conduit is not limited as to maximum size.

**Exercises (227):**

1. Match the following types of conduit or conduit fittings in column B to the correct descriptive statement in column A by placing a letter in the blank provided.

*Column A*

_____ (1) A metal conduit made in sizes of 1/2 inch through 6 inches that may be used in any location.
_____ (2) Used for connecting metal conduit to a box
_____ (3) Uses threadless couplings that must be glued.
_____ (4) Also called thin-wall, conduit uses compression fittings for coupling and connecting.
_____ (5) Used as an alternate in place of rigid because of its light weight.
_____ (6) Cannot be used in lengths over 6 feet.

*Column B*

a. Galvanized rigid metal conduit.
b. Rigid nonmetallic conduit.
c. EMT.
d. Intermediate metal conduit.
e. Flexible metal tubing.
f. Flexible metal conduit.
g. Liquidtight flexible metal conduit.
h. Locknuts and bushings.
i. Compression connector.
j. Compression couplings.

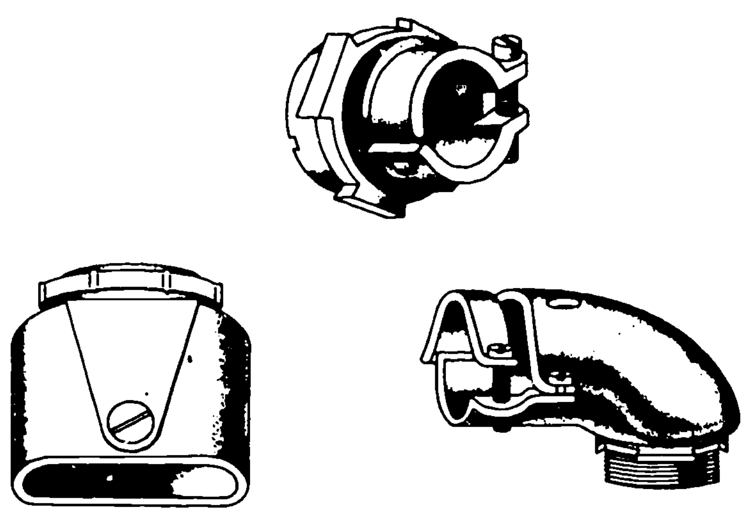


Figure 3–18. Flexible conduit fittings.

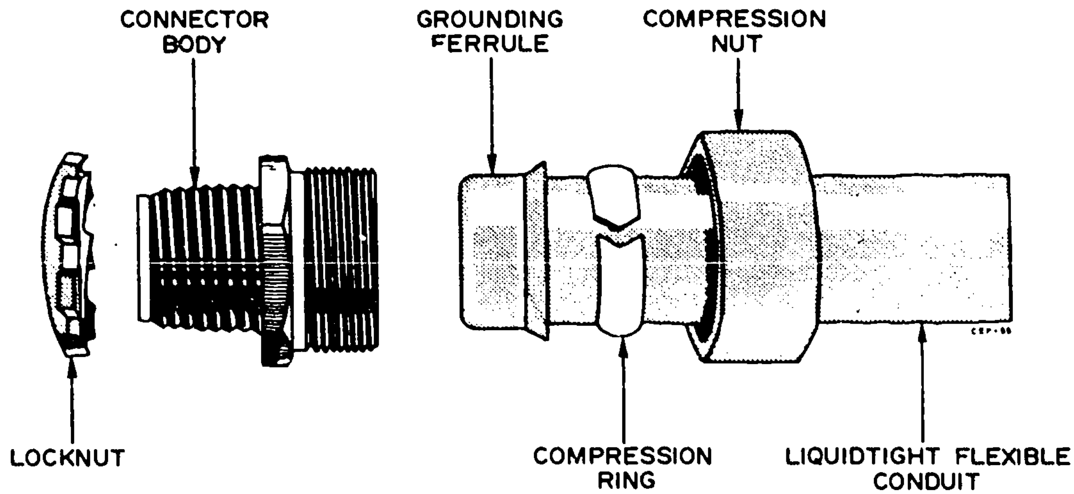



Figure 3–19. Liquidtight flex connector.

*Column A*

_______ (7) Used to fasten EMT to a box.

_______ (8) Used to fasten the ends of EMT together.

_______ (9) Used for connecting vibrating equipment that requires 6-inch electrical trade size.

_______ (10) Flexible conduit with an outer jacket.

## 3-4. Switches and Receptacles

You will find many types of switches and receptacles in interior wiring systems. Switches are necessary for energizing and deenergizing circuits and individual items of electrical equipment. On the other hand, receptacles are necessary for connecting portable electrical devices to a source of power Think for a moment. How many times each day do you throw a switch to turn on lights or operate other equipment? How often do you plug portable devices into wall receptacles? In this section, we discuss some of the switches and receptacles you will use and install.

**228. Specify the purpose of a switch, and specify the types and uses of switches required for interior wiring systems.**

**Switches.** Switches are used to connect and disconnect electrical circuits or circuit components from the power source. Operation of switches may be manual or, in some cases, automatic. In this section, you will study manually operated switches used to control circuits, or components installed in interior distribution systems. Automatic switches used for controlling motor circuits and appliances will be covered in another chapter. There are many types of switches, each type designed for specific locations and functions. Each type must be rated according to the job it is chosen to accomplish.

*Single-pole switches.* Single-pole switches are used mainly to control individual, low-amperage circuits. A good example is an ordinary lighting circuit inside a room. You turn the light switch to ON when you want to turn on the lights. You turn the light switch to OFF when you want to turn off the lights. The switch simply serves as a device for opening and closing a wire in a two-wire circuit. The single-pole switch must always be installed in the hot (ungrounded) wire of the circuit. Never install a switch in the circuit's neutral (grounded) wire. The switch contacts are inclosed in an insulating case, usually made of Bakelite. You cannot open the case to work on the contacts. A typical single-pole toggle switch is shown in figure 3-20. When a single-pole switch becomes defective, you simply remove and replace the switch.

Single-pole switches are equipped with two terminal screws for connecting the circuit wires to the switch. Each switch has a toggle (short handle), pushbutton, or some other way to open or close the switch manually. The words "OFF" and "ON" are printed on the toggle switches to visually indicate whether the switch is open or closed. Single-pole switches must always be mounted inside a switchbox. A switchplate is then installed over the switch and box. When you install a switch, mount it in the box so that the toggle points up when the switch is on. Single-pole switches are rated in amperes and volts. You must select a switch that is rated suitably for the circuit in which it is to be used. For example, a switch installed in a 20-ampere, 120-volt circuit must be rated at 20 amperes or more, and 120 volts or more.

*Double-pole switches.* These switches closely resemble single-pole switches. However, where the single-pole switch is used to open and close one wire in a circuit, the double-pole switch is equipped with four terminal screws

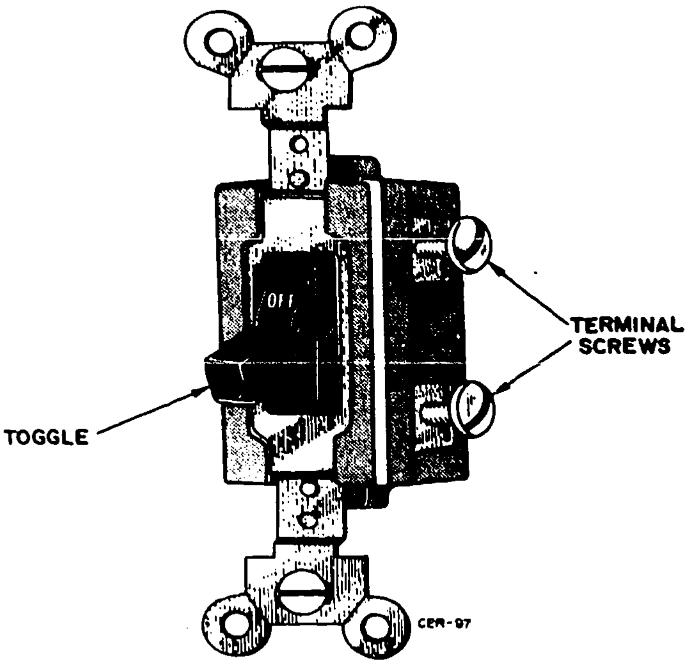



Figure 3–20. Single-pole toggle switch.

and is used to open and close both wires of a single-phase circuit. See figure 3-21. In a 240-volt, single-phase circuit, both hot wires of the circuit must be switched through a double-pole switch. Double-pole switches must be installed in the same manner as the single-pole switch. When the switch is placed to ON, the toggle must point up. The capacity (amperage and voltage) of the switch must be suitable for the circuit in which it is installed.

*Three-way switches*. Single- and double-pole switches are used to control a circuit from one location only. Where you want to control a circuit from two locations, you must use three-way switches. A three-way switch may be identified by the number of terminal connections on the

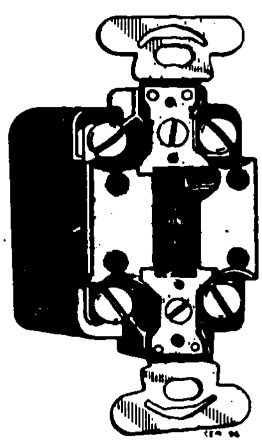


Figure 3–21. Double-pole toggle switch.

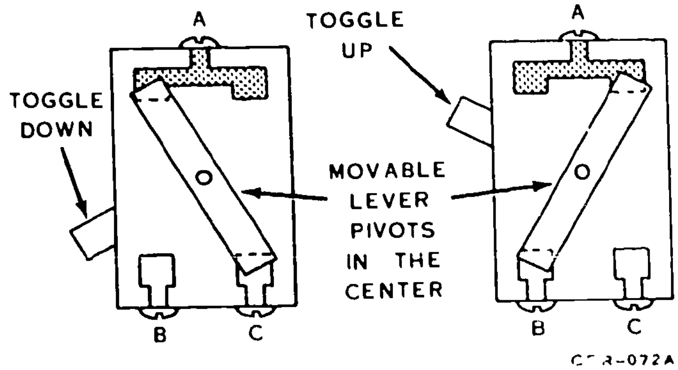



Figure 3–22. Three-way switch positions.

switch housing. It has a common terminal on one end and two traveler terminals on the other end. Unlike single- and double-pole switches, the toggle on a three-way switch is not labeled "ON" and "OFF." The switch, however, should be mounted in a vertical position. Figure 3-22 shows how the switch works internally. Screw A is the common terminal and screws B and C are the traveler terminals. Note that one position of the toggle connects screw A to C and the other position connects screw A to B. Figure 3-23 shows how two three-way switches are connected in a circuit to control a light from two points. With the switches in the positions shown, the circuit is open. If the position of either switch is changed, the circuit will be closed and the light will burn.

*Four-way switches*. In some installations, you may need to control a circuit from more than two locations. In this case, and three-way switches and any number of four-way switches may be used. With this combination, a circuit can be controlled from any number of desired locations. Four-way switches do not have the words "ON" and "OFF" printed on the switch toggle. This is because in either position (up or down), the switch may be in the ON or OFF position. Figure 3-24 shows how most four-way switch terminals are connected internally. The detail to the left shows the switch in one position and detail to the right shows the switch in the other position. Figure 3-25 shows a circuit with a combination three-way and four-way switching arrangement. The light can be turned on or off from any of the three switches. You may add any number of four-way switches to the circuit. However, all four-way switches must be connected electrically between the two three-way switches.

Three- and four-way switches are installed in outlet boxes in the same manner as are single-pole switches. The mechanical construction varies among manufacturers so that the marked (common) terminal is sometimes alone on one end of the switch or sometimes alone on one side. These three-way switches are wired as shown in figures 3-23 and 3-25, depending on the location of the marked (darker colored) terminal. Fortunately, no harm is done if the wrong terminals are selected, except that the circuit will not work. If there is any doubt as to which are the correct terminals on a switch, use an ohmmeter or continuity test

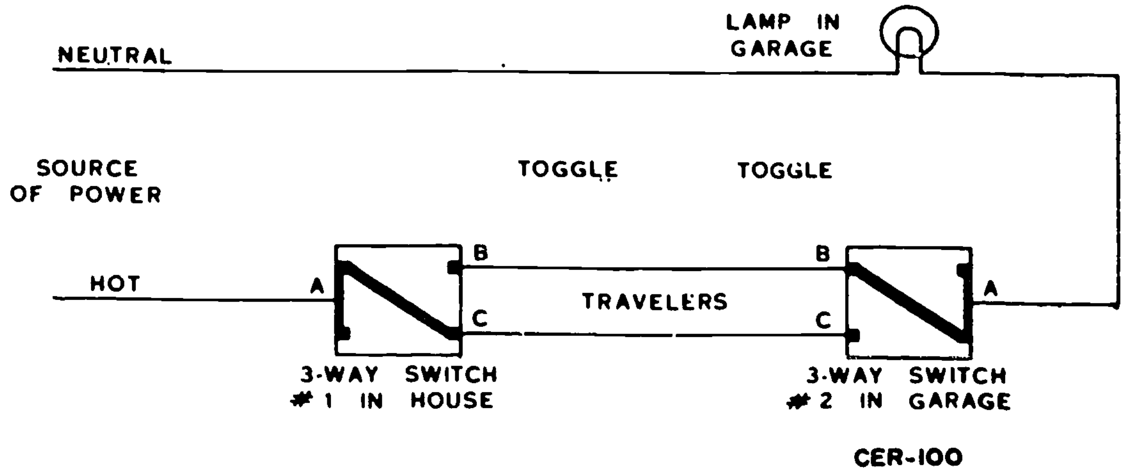



Figure 3–23. Three-way switch connection.

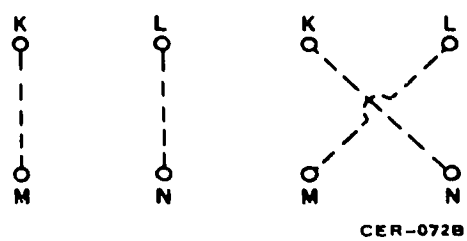



Figure 3–24. Internal connections of a four-way switch.

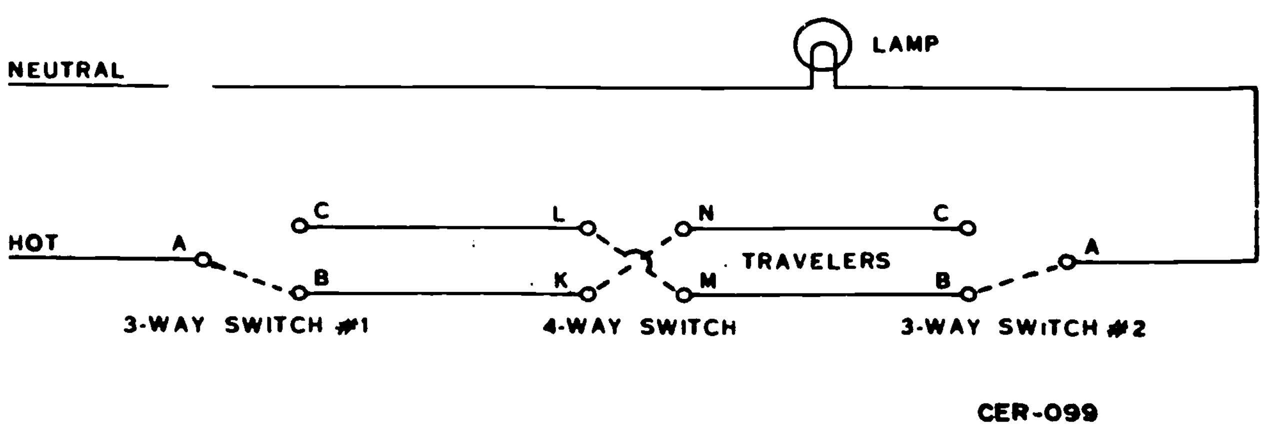



Figure 3–25. Circuit control with three-way switches.

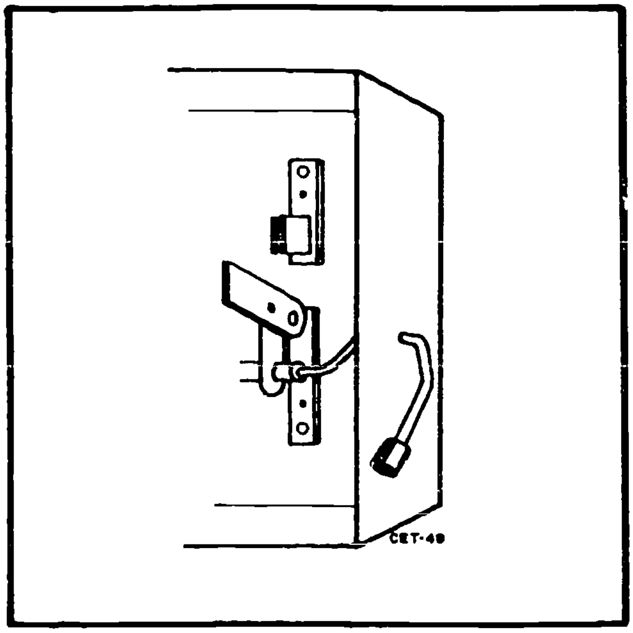



Figure 3–26. Knife-blade switch.

set to establish the proper connection sequence. It may be necessary to draw yourself a circuit with switch terminals marked to establish the correct switch wiring sequence and make it easier to hook up.

To make the installation of three- and four-way switches easier, follow these rules:

*a.* Connect the white wire from the power source to the silver terminal of the outlet being switched.

*b.* Connect the hot (black) wire from the power source to the common terminal on the first three-way switch.

*c.* Connect the hot (black) wire from the common terminal of the second three-way switch to the dark terminal of the outlet being switched.

*d.* Connect traveler wires between the switches.

*Knife-blade switches and circuit breakers.* Knife-blade switches use spring-loaded slide contacts with a movable blade and handle, as shown in figure 3-26. These switches are used to disconnect ungrounded conductors. Switches with more than one blade open all conductors at the same time. They normally are used as a main disconnect switch to cut off power to a building or a large piece of equipment. Knife-blade switches may be fused or nonfused and single or multiple throw. They must be made and mounted so that gravity will not accidentally close the switch. Normally, when the handle is in the down position, the power is off the load terminals.

Circuit breakers are overcurrent protective devices that may be used as switches. When they are used as switches, they must be inclosed in a box or cabinet. When they are used as switches on 120-volt, fluorescent lighting circuits, they must be marked SWD switches and approved for the purpose. All switches and circuit breakers used as switches must be installed so that the handle, when in its highest position, is no more than 6½ feet from the floor or working platform. Circuit breakers and disconnect switches will be covered in detail in a later chapter.

**Exercises (228):**

1. What is the purpose of a switch?

2. What switches must be used to control a light or lights from two locations?

3. What switches are required to control a light or lights from more than two locations.

4. A three-way switch has how many terminals?

5. How are single-pole toggle switches mounted?

6. How are switches rated?

7. How many terminals does a double-pole switch have?

8. Knife-blade switches equipped with three blades must open how many conductor(s) and in what order?

9. How must a circuit breaker used as a switch for a 120-volt, fluorescent light circuit be marked?

10. A circuit breaker used as a switch for a 120-volt, fluorescent light circuit should be mounted, in its highest position, so that the handle is mounted no more than how many feet above the floor?

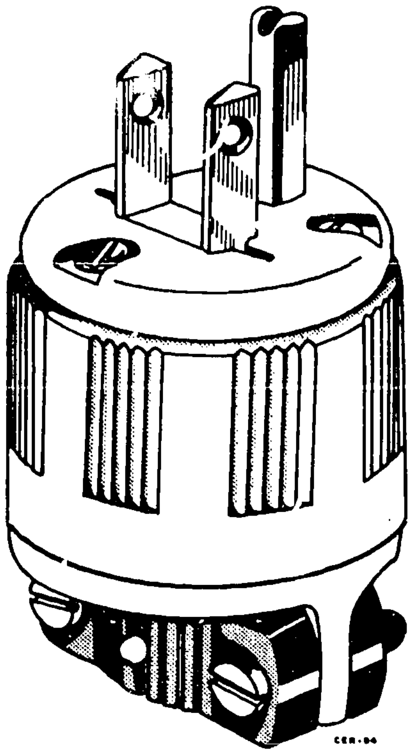


Figure 3-27. Attachment plug.

**229. State the function of a receptacle, and identify various types by their design characteristics.**

**Receptacles.** A receptacle is a device, with a set of contacts, installed in an outlet box for the connection of an attachment plug. It is commonly called an outlet or a receptacle outlet. An attachment plug (fig. 3-27) is a device with blades or prongs used to join the wires of an appliance cord to the wires of the electrical system at the outlet box. The receptacle and attachment plug often are referred to as the female receptacle and the male plug.

Receptacle outlets are used to make it easy to connect and disconnect portable appliances, tools, and other electrical devices. They are made in many types and sizes, from the 120-volt, three-wire type used in the home, to the three-phase, 600-volt, four-wire type used for special applications. The most common one is the duplex type used in your home. It has two 120-volt, 15-ampere, three-wire receptacles, as shown in figure 3-28. It is wired with a hot wire and a neutral wire that feed power to both receptacles. A third wire is used to ground equipment that is connected with a plug. Until a few years ago, two-wire receptacles were allowed by the NEC. Now, they are allowed only in homes built before the change in the NEC. If these receptacles need to be changed, they must be replaced with three-wire, grounded types, and an equipment ground must be run. In all new work, you must use the three-wire type. (NOTE: The slots of the receptacle shown in figure 3-28 are side by side or parallel. This slot arrangement is used for 120-volt outlets only. A single receptacle with the same slot arrangement is used in place of a duplex where only one piece of equipment is connected to a dedicated circuit, like the laundry receptacle.

There are several other types of receptacles used frequently in the home to connect fixed or stationary appliances. The receptacle shown in figure 3-29 is used quite often for connecting 240-volt, window-type air conditioners. The slot arrangement for this receptacle is called a tandem and is used for single-phase, three-wire outlets rated for 208/240 volts and 20 amperes. It is also available as a duplex, but is more commonly used as a single receptacle installed to feed one piece of equipment.

Another type of receptacle used in the home for connecting clothes dryers is shown in figure 3-30. This type is called a crow's foot and is a single-phase, three-wire outlet rated at 125/250 volts, 30 amperes. This receptacle is wired with two hot wires and one grounded wire. The NEC allows this receptacle to be used without an equipment ground if the grounded wire (neutral), in the appliance cord, is No. 10 AWG or larger and is bonded to the frame of the appliance. The receptacle used for an electric range has almost the same slot configuration as the one used for the dryer. See figure 3-31. The main difference is in the slot used for the neutral (white wire). The range type has a straight slot and the dryer type has an L-shaped slot. The range receptacle is wired the same way as the dryer receptacle but is rated at 50 amperes instead of 30 amperes. As you can see, both of these receptacles are single units. They are not made as duplexes and they must be protected (by circuit breaker or fuse) and wired on separate circuits. Although these receptacles have been described as dryer and range outlets, they are in no way limited to use as receptacles for these appliances. Remember, each receptacle is rated in volts and amperes and must be selected according to the rating of the equipment to be served.

The last receptacle we will discuss is the heavy-duty, industrial type. Figure 3-32 depicts a 3ϕ-480V, 5-wire receptacle and male plug rated at 100 amperes. Part C of the figure is the male plug and female receptacle connected, and mounted to an adapter ring. The adapter ring is providing a firm foundation and attached to the weatherproof conduit box.

Part A is the receptacle, mounted in a hard plastic case. The case has a spring-loaded, weatherproof cover that snaps closed when the male plug is removed. Some manufacturers use a screw on cover similar to the lid on a fruit jar. The receptacle has five slots or holes. The center hole is the equipment ground. Three of the outer holes are phases and the fourth is reserved for a control conductor.

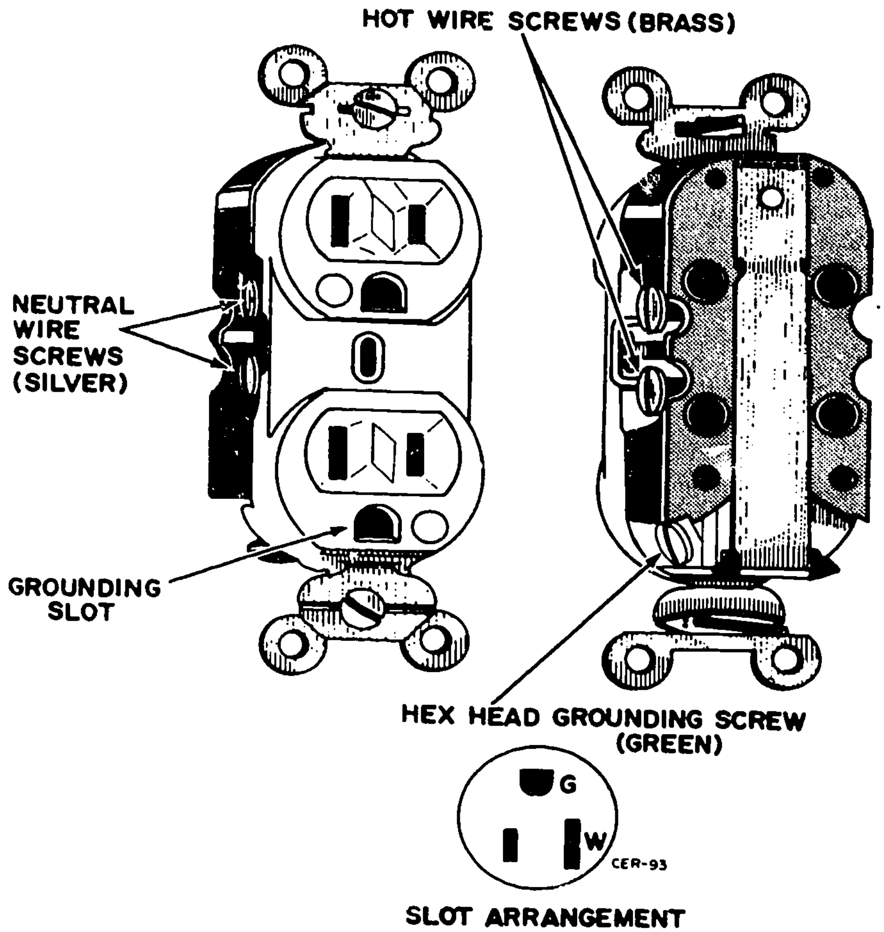



Figure 3-28. 120-volt, three-wire, duplex receptacle.

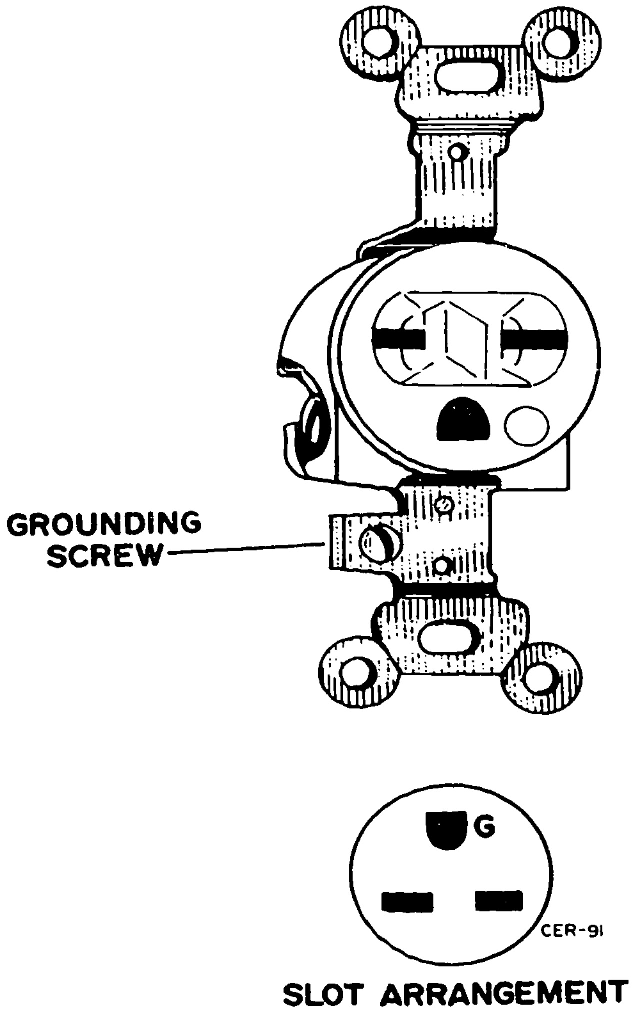



Figure 3–29. Three-wire, tandem slot receptacle.

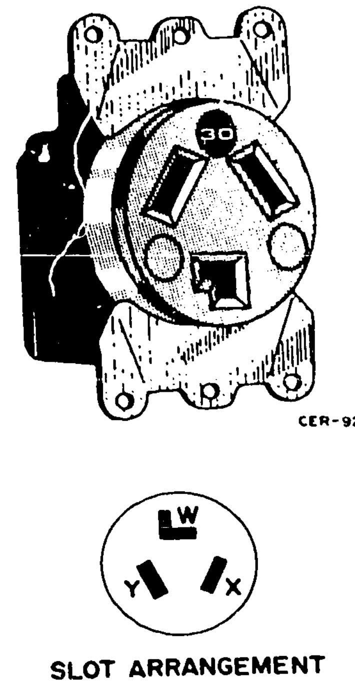



Figure 3–30. 30-ampere, crow's foot receptacle.

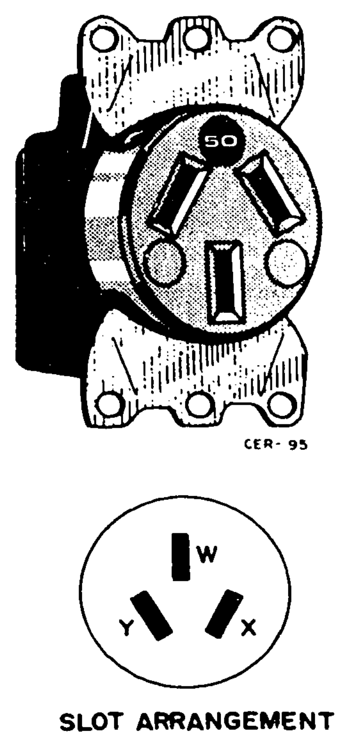



Figure 3–31. 50-ampere, crow's foot receptacle.

Part B, the attachment plug is also mounted in a hard plastic case. It has grooves on the outside of the case and must be aligned to the receptacle in only one specific position before the grooves allow the plug to enter the receptacle. The center pin is longer than the four other pins and makes contact with the receptacle's equipment ground slot before the other pins make contact with their respective slots. This is a safety precaution. The tang on the plug and cover clip under the receptacles thumb latch and provide a locking device.

Part C, the adapter ring, can be removed and mounted to almost any surface, such as a motor-starter cabinet, safety switch, or circuit breaker panel.

The industrial receptacle and plug is a special order item. Always specify the voltage, amperage, and number of contact pins required. Replacement parts should be ordered by part number from the original equipment.

Always use extreme caution when servicing or replacing these receptacles. The higher voltage and amperes encountered can be very dangerous.

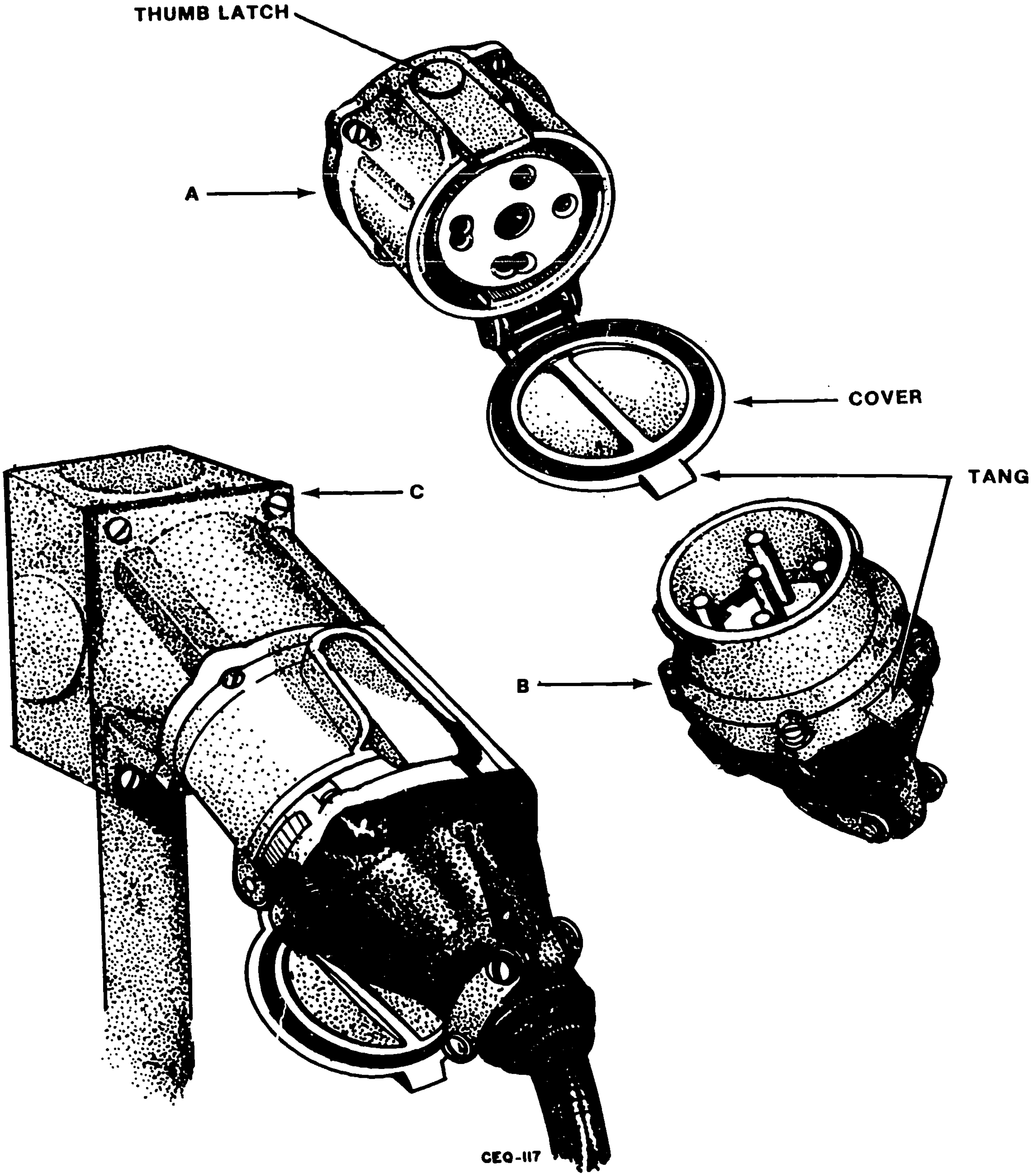



Figure 3–32. Industrial outlet and plug.

**Exercises (229):**

1. What is the function of a receptacle?

2. What is the device called that is used to complete the connection between the receptacle and the equipment being served with power?

3. What precautions should you take when ordering a heavy-duty receptacle?

4. Match the receptacle in column B with the appropriate description in column A by placing the correct letter in the blank provided.

| *Column A* | *Column B* |
|---|---|
| _____(1) Used frequently for window air conditioners. | a. 120-volt, three-wire duplex. |
| _____(2) Crow's foot, straight slot, used for ranges. | b. 208/240-volt, 20-ampere receptacle. |
| _____(3) Crow's foot, L-slot, used for dryers. | c. 125/250-volt, 30-ampere receptacle. |
| _____(4) Parallel slot, wired with an equipment ground. | d. 125/250-volt, 50-ampere receptacle. |
| _____(5) Grooved case for alignment. | e. 220/440-volt 3-phase receptacle. |
| _____(6) Special order item. | |

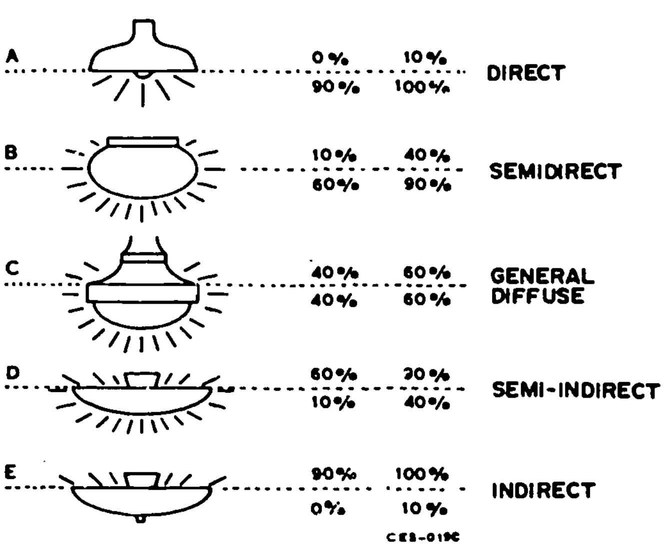



Figure 3-33. Light-fixture classification.

## 3-5. Lighting Fixtures

One of the most important uses of electricity is for lighting. As an electrician, you will be called on many times to install or repair light fixtures. In order for you to do the work required, you must know something about how light fixtures are classified and the basic types of lighting used.

**230. List the classifications of light fixtures, and identify the light distributing characteristic of each selected classification.**

**Fixture Classification.** Light fixtures, no matter which type of light source is used, are classified according to the way they distribute the light. Some fixtures are equipped with reflectors or shades to direct light downward or upward. Others are equipped with globes to direct light in all directions. Fixture classification is determined by an imaginary horizontal line at the level of the light source. The amount of light directed above and below the imaginary line determines the classification. There are five general classifications: direct, semidirect, general diffusing, semi-indirect, and indirect. These are shown in figure 3-33.

*Direct.* A direct-lighting fixture may direct 90 to 100 percent of the light below the horizontal line or toward the work area as shown in figure 3-33,A. It may be hung from or mounted to the ceiling, or recessed so that it is flush with the ceiling. A fixture of this type is most effective when used in a narrow bay or hall where the reflector is mounted at a height equal to or greater than the width of the area to be lighted. Because of the light distribution, this type of fixture directs most of the light to the work area without much loss on the walls and windows. Although direct lighting provides good light on working surfaces, it may be at the expense of other factors, such as too much contrast of the light source with the surroundings, bad shadows, or glare.

*Semidirect.* A semidirect fixture (fig. 3-33,B) is one that distributes from 60 to 90 percent of its light output downward. The remaining light is directed upward above the horizontal line. A semidirect fixture may be suspended or mounted on a ceiling; it may have the light source exposed, concealed behind a diffusing medium made of glass or plastic, or behind a louver. Although these units are essentially direct lighting in the quality of light produced, some added indirect light is obtained if the ceiling is light in color. The upper light contributes to comfort and good appearance by brightening a light-colored ceiling and reducing sharp contrasts between the unit and its background.

*General diffusing.* A general diffusing fixture distributes from 40 to 60 percent of its light upward above the horizontal line, as shown in figure 3-33,C. It can be suspended or mounted on a wall, ceiling, or pedestal. Its light source is concealed in a d[illegible]edium. One widely used unit is the glass-inclosin[illegible]e for use with filament lamps. This type is simple, relatively low in cost, and produces good light on vertical surfaces. Where greater illumination is desired from existing fixtures, the next

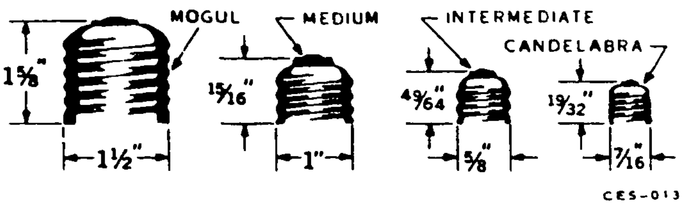



Figure 3–34. Lamp bases.

higher wattage lamps sometimes may be installed. If the globes become uncomfortably bright, large-diameter globes should then be used.

*Semi-indirect*. A semi-indirect fixture distributes from 60 to 90 percent of its light above the horizontal line and from 10 to 40 percent of its light below, as shown in figure 3-33,D. The light source is concealed from view below the horizontal line by a diffusing medium, usually glass or plastic. Because the ceiling is an important part of this lighting system, it must be white (or nearly white) and well maintained. Fixtures of this class are available either completely inclosed, open top, or open bottom. The latter two types simplify maintenance.

*Indirect*. Indirect-lighting fixtures (fig. 3-33,E) distribute from 90 to 100 percent of their light output upward above the horizontal line. They may be suspended or mounted on the wall or a pedestal. The light source is concealed from view below the horizontal line. Indirect-lighting fixtures direct practically all their light to the ceiling and upper side walls so that the entire ceiling becomes the light source.

**Exercises (230):**

1. How are light fixtures classified?

2. What are the light fixture classifications?

3. What percent of light is directed above the horizontal in the semi-direct classification?

4. What percent of light is directed below the horizontal in the semi-indirect classification?

5. In which light fixture classification is the light source concealed from view below the horizontal?

6. Which light fixture uses the entire ceiling as a light source?

**231. Identify characteristics of incandescent and fluorescent lighting.**

**Types of Light.** There are three types of lighting: incandescent, fluorescent, and high intensity discharge lamps. These are discussed below.

*Incandescent lighting*. The term "incandescent" means glowing or white with heat. Thus, the light given off by an incandescent lamp (common light blub) is the result of current flow through the lamp filament. The current heats the filament to a white-hot condition. While the filament is in this state, it emits light. Although there are more efficient electric light sources, the incandescent lamp is not obsolete. It is often preferred for many uses because of its economy, flexibility, ease of maintenance, and convenience. Incandescent lamps are easy to get, easy to replace and clean, and small in size. They require no auxiliary equipment as do other types of lamps. Where accurate control of light distribution or a beam is required, the incandescent lamp is most useful. There are, however, some disadvantages to incandescent lighting. It is too rich in red and yellow light rays, which changes the appearance of some colors. It is less efficient than other types of electric lighting because some of the wattage is wasted as heat.

In order to use incandescent lamps, you must have some type of lampholder or socket. Most sockets are mounted in plastic, porcelain, or a similar material so that they can be installed in a light fixture. The light fixture is then mounted on the ceiling or wall and controlled by a switch in the wall. Lampholders used in table or floor fixtures usually have their own switch.

Incandescent light sockets are classified according to the size of lamp base they will accommodate. Lamps are made in a variety of sizes and wattage ratings. In most cases, the larger the wattage rating, the larger the lamp. This is also true of the base. There are four base sizes used for incandescent lamps, as shown in figure 3-34. Although there are other types most lamp bases are the screw type that allows the base to be threaded into the socket.

*Mogul socket*. The mogul socket is the largest size in use. It accommodates incandescent lamps rated from 300 through 1500 watts. The maximum voltage rating for these sockets is 600 volts. Mogul sockets are used where lighting is required in high bay areas (hangars, shops). They are also used in flood-lighting and street-lighting systems. Mogul sockets generally are made of porcelain to withstand the great amounts of heat generated by the high-wattage lamps.

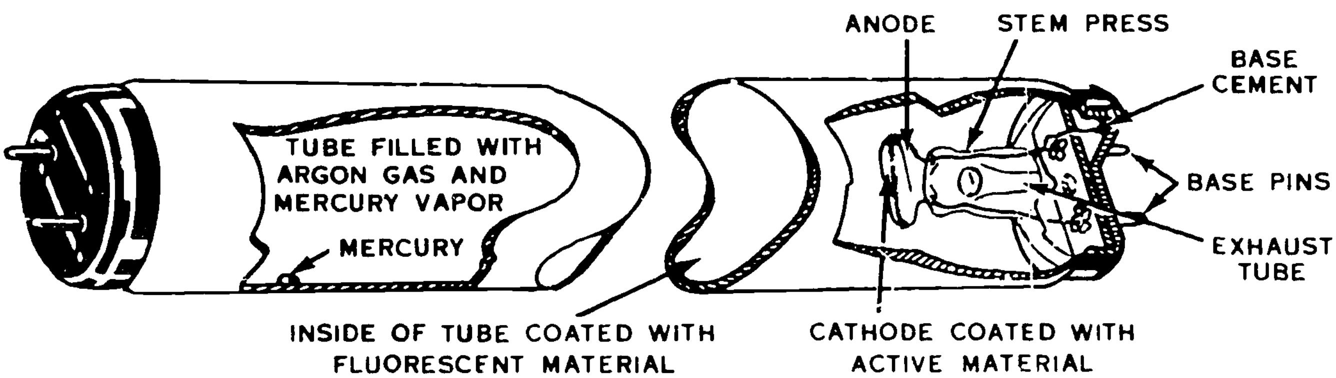
*Medium socket*. This is the most common lamp socket used in general lighting systems. It accommodates lamps rated from 10 through 300 watts. The maximum voltage rating for the medium socket is 250 volts. The sockets are made of plastic, porcelain, and brass. They may be designed for mounting on a wall or a ceiling, or hung by cord.

*Candelabra and intermediate sockets.* These are the smallest screw-type sockets in general use. They are used mainly on panelboards and other equipment to illuminate dials and gages. They are used also for ornamental lighting. A string of common Christmas-tree lights is a good example of lighting with candelabra sockets. A candelabra-base lamp is a low-wattage lamp. The maximum wattage rating is 75 watts, while the maximum voltage is 125 volts. The intermediate-base lamp is a little larger, with a maximum voltage rating of 250 volts. Both the candelabra and the intermediate sockets are made in either plastic or porcelain. The development of the fluorescent light has provided a method of lighting that gives a high rate of efficiency per watt of electricity used. A fluorescent light gives two to three times as much light as an incandescent light of the same wattage. Since a fluorescent light uses less wattage, it produces less heat. This is an important factor to consider where air conditioning is used.

There are three basic types of fluorescent lights: the preheat (hot cathode), the rapid start, and the instant start (cold cathode). Each type has some equipment common to all types but they may vary slightly in operation. The common parts are the lamp or tube, the ballast, and the lampholder. The fluorescent lamp is an electronic device that operates basically the same way regardless of the type of ballast or lampholder used. It is made up of a long, straight, or circular glass tube that contains a drop of mercury and a small amount of argon gas. Electrodes are sealed into the lamp at each end. Both electrodes are made so that they can act as cathodes (emitters of electrons). Figure 3-35 shows a cutaway of the fluorescent lamp. The lamp conducts in both directions for alternating current flow. The inside surface of the tube is coated with a fluorescent chemical. The chemical used determines the color of the light.

*Preheat starting.* The preheat start fluorescent light fixture requires an additional piece of equipment, not required by the other types, called a starter. The main purpose of the starter is to provide a path for current flow through the lamp electrodes until the argon gas inside the lamp reaches a conducting state. After an arc is struck from electrode to electrode and the lamp lights up, a switch in the starter opens and the starter is no longer in the lamp circuit. The ballast performs a twofold purpose. First, it provides a high induced voltage to strike an arc through the tube. Second, it stabilizes the operating current of the circuit.

When a fluorescent lamp reaches the end of its life through deactivation of the cathodes, the starter continues to try to start the lamp each time the arc fails. The result is a more or less continuous preheating of the cathodes. Since the preheating current is more than the operating current, there is an increase in ballast heating. If lamps are not



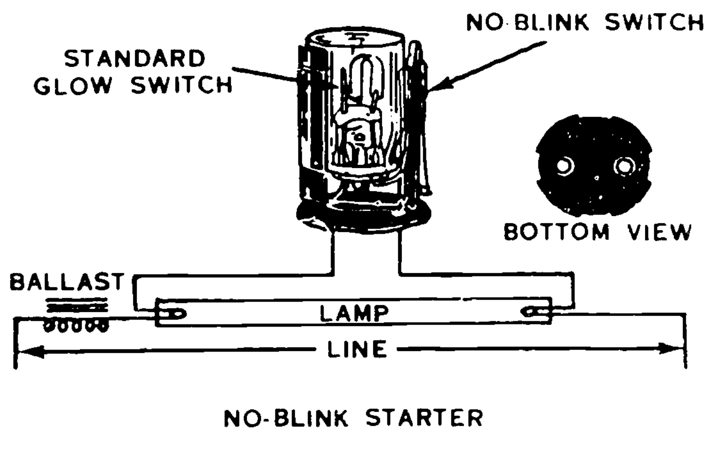




Figure 3-35. Flourescent lamp and no-blink starter switch

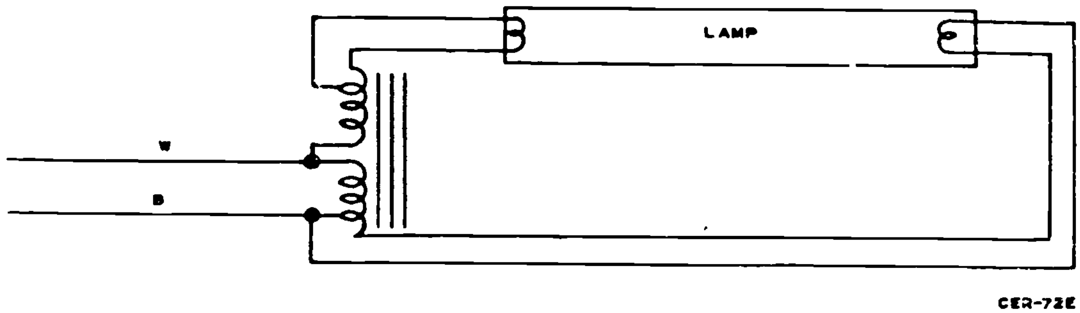



Figure 3-36. Rapid start circuit.

turned off or removed promptly, the resulting temperature rise may cause damage to the ballast and may ruin the starter. To prevent this, cutout or no-blink starters are used. These have a thermal strip that opens the starting circuit after a limited number of attempts to start the lamp. Some of these cutout arrangements are automatic in resetting, but others require manual reclosing. Refer to figure 3-35 again for the cutout or no-blink starter.

The electric discharge of a ballast vaporizes the mercury in the tube to produce ultraviolet rays that activate the fluorescent chemicals on the inside of the tube. This activation causes the chemical coating to glow, thereby producing light.

*Instant starting*. Hot-cathode starting is called preheat starting, while cold-cathode starting is called instant starting. With the cold cathode, the lamp lights instantaneously upon closing of the lamp circuit. The preheat start lamps are made with bipin bases at each end. The instant-start lamps are made with either bipin or single-pin bases at each end; in either case, the filament of instant-start lamps is short circuited in the base. The reason for making some of the instant-start lamps with bipin bases is so they may be used in conventional bipin lampholders that are equipped with an instant-start ballast.

The cold-cathode, or instant-start, fluorescent circuit contains a ballast but no starter. The ballast supplies a high voltage across the filaments of the lamp when the circuit switch is closed. This high voltage instantly vaporizes the mercury in the lamp. At the same time, an arc is struck through the conductive mercury and argon, thus completing the circuit between the lamp filaments. This causes the lamp to glow. The ballast then regulates the voltage for normal operation.

*Rapid starting*. The most common fluorescent fixture used is the rapid start. The starting means for the rapid-start system is built into the ballast. Part of the ballast is is tapped to provide low voltage to heat the lamp electrodes. (See fig. 3-36). The heating will cause ionization of the gas in the tube and allow an arc to strike across the lamp. The high voltage needed to help strike the arc comes from the main winding of the ballast. The fast and continuous heating of the electrodes reduces the amount of voltage needed to strike the arc so that the size of the ballast can be made smaller. The rapid start light will start more quickly than the preheat light, usually within 1 or 2 seconds. Like the preheat lamps, rapid-start lamps use the bipin base. For this reason, they are interchangeable with the preheat lamps.

**Exercises (231):**

1. What type of lamp is preferred because of its economy and ease of maintenance?

2. What type of lamp is disadvantaged because it gives off excessive red and yellow light rays?

3. What socket will accept a 1000-watt incandescent lamp on 277 volts?

4. Which size of incandescent lamp socket is made of several materials including brass?

5. What type of incandescent lamp socket is normally associated with ornamental lighting?

6. What size of incandescent lamp is required to produce the same amount of light as a 40 watt fluorescent tube?

7. What is the basic principle of operation for any fluorescent tube when the ballast is energized?

**232. Compare high intensity discharge lighting with incandescent and fluorescent lighting, and identify their design characteristics and applications.**

***High intensity discharge (HID) lighting.*** Efforts to improve the power efficiency and reduce the maintenance costs led to the development of a new family of lighting generally categorized as the electric discharge lamps. These lamps all have a negative resistance characteristic. This means that the resistance decreases as the lamp heats up. This normally would cause the current flow to increase. Lamps of this type must be equipped with a current limiting device called a ballast. Lamp life and more light per watt are the two main advantages that electric-discharge lamps have over incandescent bulbs. The basic types of electric-discharge lamps used in area lighting are vapor lamps, and metal halide. Figure 3-37 shows the basic configuration of vapor and metal halide bulbs. In these lamps, a material, such as sodium, mercury or metal halides of thallium, sodium, or indium, in addition to mercury, is added to the arc tube. In design, the lamp has three electrodes with one electrode being used only for starting. This starting electrode is connected to the bottom main electrode. The arc tube contains a small amount of pure argon gas to aid in starting. Free electrons are accelerated by the starting voltage. In this state of acceleration, these electrons strike atoms and displace other electrons from their normal atomic positions. Depending on the gas involved, radiations of a specific wavelength result when the electrons return to their normal atomic position. Once the discharge begins, the inclosed arc becomes the light source. One main electrode becomes the anode, and the opposite electrode becomes the cathode. These functions will change with the polarity change. This function accounts for the stroboscopic effect that all HID lights exhibit. The addition of the metal halides to the arc tube results in a bulb with a 50-percent higher efficiency and better color quality over the mercury arc bulb. The latest development in HID lamps resulted from the invention of a means of effectively sealing metal ends and electrodes to a tube of special ceramic material in a combination that can withstand the temperatures and corrosive situation produced by the hot, alkaline metal vapors used in the tube. The arc produced in this lamp is mostly metallic sodium. While sodium has been used in the past, the color of light produced has been its main drawback. The new high-pressure sodium light is smaller and has a better color. This light has the highest light-producing efficiency of any white light source that is produced commercially.

Commercial companies that produce these light bulbs claim a 100-percent increase in lamp life over incandescent bulbs that will produce the same amount of light. The power in watts required to operate HID lights compared to filament lamps is less than one-half. The initial cost of the components for HID lights is greater because these lights will require ballasts; however, this cost will be made up by the savings of energy costs.

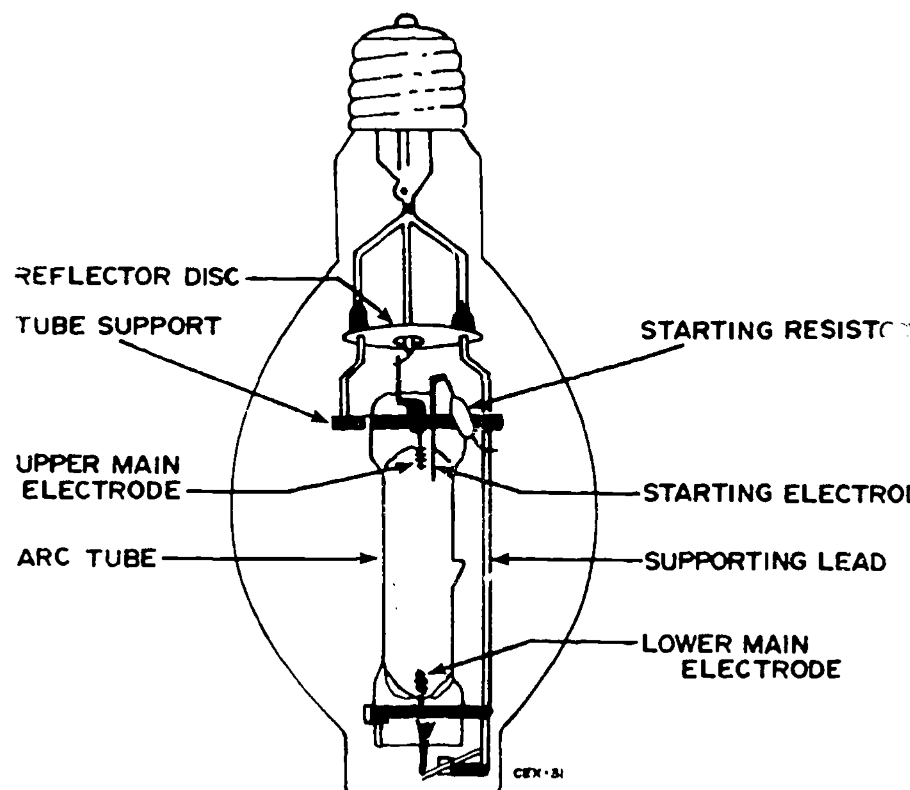



Figure 3-37. Vapor and metal halide bulb configuration.

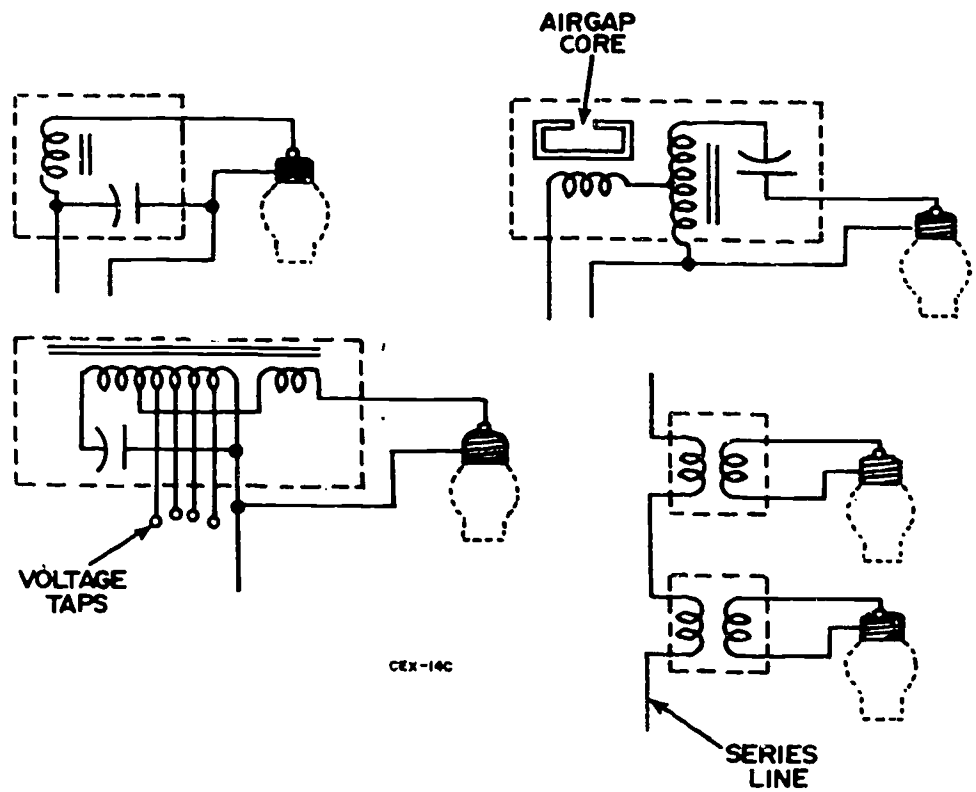



Figure 3–38. Schematic of vapor lamp and transformer connections.

Most HID fixtures are supplied with the required ballast installed in the fixture. In some cases, ballasts, usually called current-limiting transformers, are externally installed. Figure 3-38 shows schematics of mercury-vapor lamps and transformer connections.

*Lamps*. HID lighting systems are being used more and more by the Air Force for two reasons: longer bulb life and greater energy efficiency. Longer bulb life results in lower maintenance (relamping) costs. Greater energy efficiency, simply stated, means more light (lumens) per watt of energy. As a comparison between incandescent bulbs and HID bulbs, an incandescent bulb that consumes 575 watts provides 10,000 lumens and has a lifespan of 1200 hours while a metal halide lamp at 400 watts provides 32,000 lumens and has a lamp life of 10,500 hours. A high-pressure sodium HID bulb of 400 watts consumption provides 42,000 lumens with a life of 6000 hours. As you can see from these examples, the HID lamps far surpass the older incandescent lamps in light bulb life and efficiency. The economic life of the HID bulbs range from 6000 to 20,000 hours. Lamp temperatures should be maintained below 210° F at the base and should not exceed 400° F outer bulb temperature. Specific voltages are required for these lamps and should not vary more than 5 percent above or below this specified rating. Low voltages will cause the lamps to go out. Normally they will not restart until the internal vapor pressure is reduced to a point where the arc can be restarted. This time may vary from 4 to 8 minutes. The existing conditions will govern this time. Where extremely cold conditions exist, such as street-light or flood-light systems in winter temperatures, specially designed ballasts (transformers) are installed to provide a higher open-circuit voltage to aid in starting the lamps.

As a general rule, mercury HID lamps are used for street and highway or high bay lighting of large installations. Metal halide and high-pressure sodium lamps are used where color rendering quality of light is important, such as street lighting, floor lighting, and recreational lighting.

It should be remembered that all HID lights produce a stroboscopic effect and, when possible, adjacent lamps should be powered from different phases to reduce the results of this effect.

*Fixtures*. Each manufacturer of HID lighting system provides a wide variety of fixtures to meet all lighting configurations. Various styles and mountings are available to fit any decor or situation.

Most fixtures will have provisions for mounting ballasts (transformers) within the fixture and will provide protection for the ballast. In some cases, particularly in high bay lighting, the ballasts may be mounted at some central location and not mounted in the fixture. A portion of the HID lamps are manufactured with the ballast built into the lamp envelope. They can be interchanged with incandescent lamps using mogul sockets and proper voltage.

The location and job determine whether the fixture is

suspended, bracket mounted, or arm mounted. Most brackets can be attached either to wood or metal support structures. In either case, the fixture should be attached firmly to the structure so that precise aiming for light distribution can be made.

Another factor to be considered when ordering fixtures is the type (diffused or bright) of lighting that is desired. Fixtures will also be designed for bulb position, installation (base up or base down), and adequate cooling of the bulb. High-pressure sodium and metal halide bulbs are screw-based (Edison) and of the mogul size. Make sure that the lamp base and the fixture base are compatible when ordering.

*Power Distribution.* If a system is simply being upgraded by changing incandescents for HID lamps, the present wiring is most likely adequate to handle the change since the HID lamp requires less power than the older incandescent system. Either a series or a multiple-wiring parallel system may be used. In some cases, isolating transformers are used in conjunction with the lighting fixture on a series system.

WARNING! All HID lighting should be considered high-voltage equipment. Always match your lamps to the ballast installed. Never relamp or work on these systems while the power is on.

**Exercises (232):**

1. What led to the development of the discharge lamp?

2. Why does the resistance of a HID lamp decrease as the lamp heats up?

3. What are the main advantages that HID lamps have over incandescent bulbs?

4. What causes the stroboscopic effect that all HID lights exhibit?

5. If an incandescent bulb lasts 1200 hours, how long should a HID lamp of the same wattage last under normal conditions?

6. As a general rule, what type of HID lamp would be installed in an aircraft hangar?

7. What type of lamp should be installed for floodlighting or ballfield lighting?

8. Explain the various provisions for mounting ballasts (transformers) on HID lighting systems.

9. What factors should you consider when ordering HID lighting fixtures?

10. What is required of the circuits when changing an incandescent system to a HID lighting system?

# Installation of Services and Distribution Panels

ALMOST ALL of us depend upon electricity to do many things. It provides us with lights for seeing. It is often used to cook our food, warm us in the winter, and cool us in the summer. Electricity powers a tremendous variety of equipment used in the manufacture of industrial products helps us to do a great number of tasks quicker and easier. Such widespread use of electricity requires the installation of many facilities, starting with the generating unit. Finally, the electric system must be installed to carry the electricity from the distribution lines into the industrial facilities, shops, business establishments, schools, and homes where it can be used conveniently to provide us with goods, services, food, and comfort.

Before continuing this discussion, we should point out that the information in this volume is general in nature. It is based on recognized procedures and on the *National Electrical Code*. However, it does not cover all the conditions, details, requirements, and exceptions written in the NEC. For example, the NEC allows a number of conductors and conductor protection combinations to be used between the service drop and the building interior. Only two of these methods will be discussed here. Also, the detailed discussion will be limited to the installation of a three-wire, single-phase electrical system. You should consult the NEC for guidance on specific requirements.

## 4-1. Types of Electrical Systems

The starting point for interior wiring is the service entrance that is connected to the service drop. The service entrance is made up of several components, but before we get into the specifics concerning it, let's take a quick look at the wiring systems used inside buildings.

**237 Identify the types and characteristics of electrical systems suitable for interior wiring.**

The types of electrical systems installed inside a building are determined mostly by the use of the building and the type of electrical equipment that is to be operated. Generally speaking, electrical loads are divided into three categories. The first of these consists mostly of lighting requirements with some need for motor operation. The second category consists of a fairly heavy lighting load combined with a moderate requirement for power equipment. The third class consists mostly of power equipment with a relatively small lighting load. Under normal conditions, the power needed to meet the use requirements will be provided from the distribution system.

**Two-Wire, Single-Phase.** The simplest wiring system is a two-wire, single-phase system, which is used in small structures where the main need is for lighting. It can also be used to operate 120-volt appliances and motors. A two-wire system consists of one insulated conductor and one (grounded) conductor, as shown in figure 4-1. The ungrounded or hot conductor is black or any other color except white, natural gray, or green. The neutral (grounded) conductor is white or natural gray in color. This system is limited to operation of 120-volt equipment and relatively light loads of about 50 amperes or less. Larger loads require the use of larger and more expensive conductors. Such loads can be better served by another type of system. The two wire system requires the use of an equipment grounding conductor that may be a separate conductor, conduit, or other recognized means of grounding.

**Three-Wire, Single-Phase.** Another wiring system is the three-wire, single-phase system used for both lighting and power. This system, illustrated in figure 4-2, uses two ungrounded conductors and a neutral conductor. The neutral conductor is grounded. This system provides 120 volts between each ungrounded conductor and the neutral. It also provides 240 volts between the two ungrounded conductors. Lighting loads and 120-volt appliances and motors are wired between either of the ungrounded conductors and the neutral. Heavier loads, such as air-conditioners, heating equipment, and larger powered equipment, are wired between the ungrounded conductors to take advantage of the greater efficiency of 240-volt operation. This system provides up to twice the power that is available from a two-wire system with the same size conductors if the load is balanced between the two ungrounded conductors. It is the most common system used in residences today. This system also requires the use of an equipment grounding conductor.

**Three-Phase, Three-Wire.** A second type of three-wire system is used when the load requirement is for power. This system, shown in figure 4-3, uses three ungrounded conductors each of which is a phase. This is commonly referred to as a three-phase, three-wire system. It is used to furnish power, usually 240 volts, to installed equipment. If some lighting is needed, 240-volt fixtures and bulbs can be installed. When substantial amounts of power are required, higher voltages such as 480 or 600, may be provided with this type of system.

**Three-Phase, Four-Wire.** The last type of wiring system in common use is the three-phase, four-wire system. This system has three ungrounded phase conductors plus a

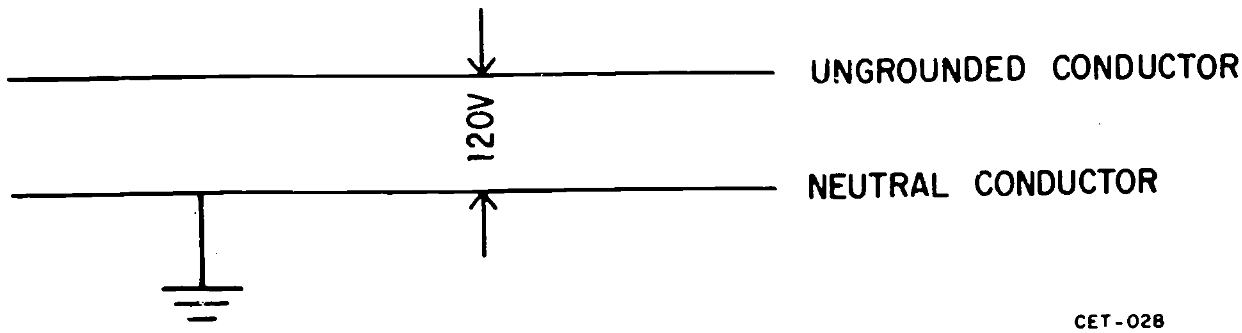



Figure 4–1. Two-wire, single-phase system.

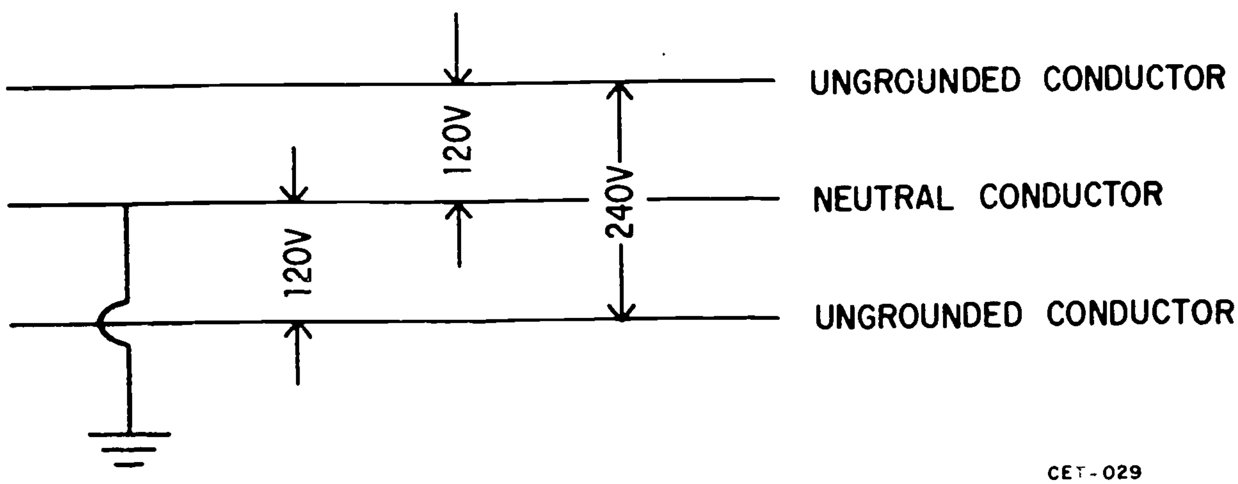



Figure 4–2. Three-wire, single-phase system.

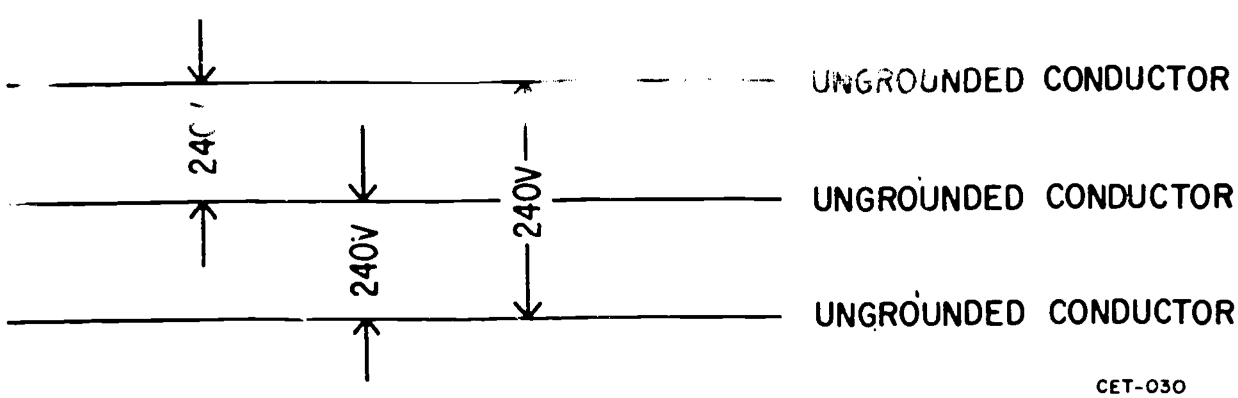



Figure 4–3. Three-phase, three-wire system.

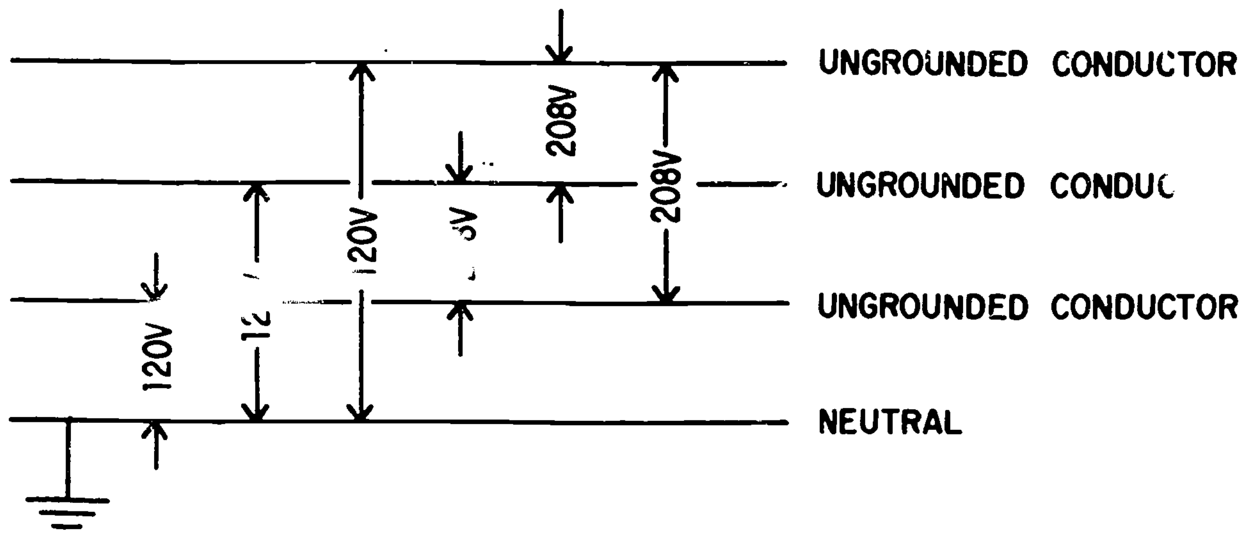



Figure 4-4. Three-phase, four-wire, wye system.

grounded neutral, as indicated in figure 4-4. It is a combination light and power system and offers quite a cost reduction over a three-wire, single-phase system for the same amount of power. The usual voltages are 120/208 or 120/240, depending on the type of transformer connections used. A wye transformer hookup provides 208 volts phase to phase and 120 volts from any phase to neutral. On a delta transformer hookup, 240 volts are available between phases. The neutral is attached midway of one of the phases. This arrangement provides 120 volts between two of the phase conductors and the neutral. However, the voltage between the third phase conductor and the neutral is another matter. It is much greater than 120 volts—over 160, which is enough to damage or ruin any 120-volt equipment that might get connected between the third phase and the neutral. This third phase is referred to as the wild leg or stinger.

NEC 230–56 requires this higher phase to ground will be marked permanently with the color orange. This requirement [illegible] wiring system when the wild leg [illegible] the same enclosure as the neutral conductor.

N[illegible]) states, "The phase arrangement on three-phase busses shall be A, B, C from front to back, top to bottom, or left to right, as viewed from the front of the switchboard or panelboard. Phase B shall be that phase having the higher voltage to ground on 3ϕ, 4-wire delta connected system."

**Exercises (233):**

1. List the general categories of electrical loads that are found in buildings.

2. What type of electrical system would be needed to service a small building with lights only?

3. What type of wiring system is needed in a residence where an electric range and dryer will be installed?

4. A pumphouse is being wired to provide power for three heavy duty pumps. The pumps operate unattended, starting and stopping automatically. What type of electrical system would this pumphouse most likely have?

5. A building is to be provided with electrical power to operate several pieces of equipment [illegible] by 208-volt motors ranging in size from [illegible] horsepower. There is also a requirement for a large amount of lighting. What type of electrical system is needed in this building?

6. A building is provided power with a three-phase, four-wire system with a delta transformer hookup. Why can only two phase conductors be used to provide power for the lighting system?

7. Explain the delta wild leg requirements in regard to color coding and phase relationship on panelboards.

## 4-2. Service Drops and Entrances

The service entrance begins where the service drop ends. Before we get into the service entrance, let's take a brief look at the service drop and see how it ties in with the service entrance.

**2-4. Specify the function and installation requirements of the basic components for the service drop and service entrance.**

**Service Drop.** The service drop is made up of conductors that run from the distribution system to the building structure. It may consist of two, three, or four wires, as discussed in the preceding objective. The service drop may be connected directly to a transformer or to the secondary distribution lines to which the transformer is attached, if the transformer furnishes power to several buildings. The service drop may consist of individual conductors strung from origin to termination or the conductors may be twisted into a multiconductor cable that may use a carrier cable for support. Multiconductor cables are attached to buildings or other structures by fittings approved for the purpose. Individual conductors are attached to approved fittings or to porcelain insulators firmly anchored to the building or other structure. Quite often, a service mast (fig. 4-5) is used to anchor the service drop.

The NEC requires that building attachment points for service drop conductors provide for certain minimum clearances. The service drop cannot pass closer than 8 feet above a flat rooftop or less than 3 feet over the peak of a roof with a slope of less than 4 inches per foot. The attachment point must not be less than 10 feet above ground or sidewalk level, or less than 15 feet above residential driveways and commercial areas such as parking lots and drive-in establishments that do not have truck traffic, and no less than 18-foot clearance for all other areas, such as public streets, alleys, and roads. The service drop cannot be attached less than 10 feet above a platform or closer than 3 feet horizontally to a window, porch, or fire escape. Conductors attached above a window are considered out of reach of the window and do not have to meet a distance requirement

**Service Entrance.** The service entrance serves to bring power from the service drop to a panelboard inside the building. Naturally, one of the components of the service entrance is the conductor through which the current flows. This conductor may consist of individual wires that run through a protective raceway, such as rigid metal conduit, electrical metallic tubing, or rigid nonmetallic conduit. The raceway provides the conductors with protection from both physical and weather damage. Power may also be brought into a building with service entrance cable. This cable does not need raceway protection unless it is likely to be damaged physically by abrasion or from being struck by passing equipment

A service head, also called a weatherhead (fig. 4-5), is used with a raceway to provide an entrance for the conductors into the raceway. The service head is designed to prevent the entrance of rain into the raceway. The

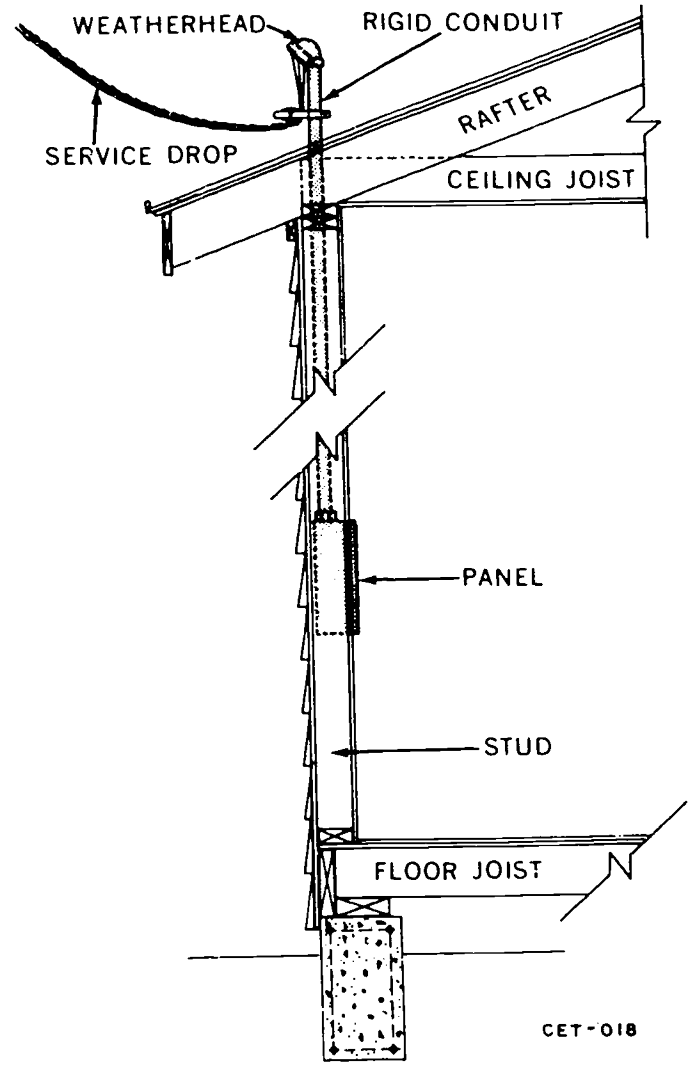



Figure 4-5. Service mast and service entrance.

conductor holes in the service head are bushed to reduce abrasion on the insulation. A service head can be used on a service entrance cable or the service entrance cable can be formed into a gooseneck to keep rain out. When a gooseneck is used, the gooseneck is taped and painted or taped with a self-sealing, weather-resistant therm ic.

Power delivered to the building may need to be measured to determine how much is used. When this is necessary, a meter socket is installed in the service entrance conductors so that a wattmeter may be included to record power consumption.

The service entrance must provide a means of disconnecting the power supply from the interior building circuits. A service disconnect or main switch can be used to turn off all interior power in case of a fire or other emergency condition. It is also useful when work is to be performed on the panelboard or work is done on several circuits at the same time. Overcurrent protective devices are required for the service conductors in conjunction with the

service disconnects. Several types of service disconnects are permitted. One of these is in the form of a knife-blade switch with one, two, or three blades, as needed, to open the ungrounded conductors. Another type of disconnect is installed as a fuse block. The fuse block contains a fuse for each ungrounded conductor. Removal of the fuse block has the same effect as opening a switch to interrupt current flow. A third method of providing for service disconnect and overcurrent protection is to use circuit breakers. These may be installed as a multipole assembly with a single switch handle. It is also permissible to use up to six switches or circuit breakers as a disconnect. Single-pole switches or circuit breakers installed on a three-phase circuit should be equipped with handle ties or a master handle. The service disconnect must be marked permanently to identify it as a service disconnecting means. Power- operated service disconnects are required to be designed so they can be opened manually.

The service entrance terminates in the service equipment or in a panelboard. The panelboard may be used for lighting and power branch circuits, or it may be used as a distribution panel for feeder circuits. The grounded conductor is not normally switched; but, when it is, the switch must be in the form of a circuit breaker and all the ungrounded conductors must open simultaneously with the grounded conductor. Regardless of whether it is switched, the grounded conductor has to be fixed so it can be disconnected. A terminal or bus bar to which all grounded conductors can be attached by means of pressure connectors meets this requirement.

The service entrance must be grounded to a low resistance ground. Normally, a pipe in the water system is used as one of the grounding electrodes. If for some reason the water system cannot be used, the metal structure of the building may serve the purpose or metal rods may be driven into or buried in the ground as a grounding electrode. Once a suitable grounding electrode is identified, the grounded or neutral conductor must be attached to it. The grounding-electrode conductor is installed as a continuous conductor from the neutral bus bar to the grounding electrode. Small grounding conductors are inclosed in a protective metal covering that should be electrically continuous from the panelboard cabinet to the grounding electrode. Metal raceways, meter sockets, panelboard cabinet's and the grounding electrode conductor inclosure must all be electrically bonded together and to the grounding electrode conductor so as to be electrically continuous. This arrangement results in all metal parts and inclosures in the service entrance and the grounded conductor being at the same potential electrically.

**Exercises (234):**

1. List the main parts of the service drop and describe their function.

2. What is the minimum clearance above the ground that the service drop may be attached to a building?

3. How far must a service drop clear an alley?

4. When a service drop is attached to the side of a building, how far must it be away from the side of a window?

5. What components make up the service entrance system?

6. What is the purpose of the service entrance system?

7. What is the purpose of the raceway on the service entrance system?

8. A service head performs what function in the service-entrance system?

9. How can water be kept from entering a service-entrance cable when a service head is not used?

10. How can the amount of power used in a building be determined?

11. Describe the arrangement and purpose of the service-entrance disconnects.

12. List three types of service-entrance disconnects.

13. For what must power-operated service disconnects have a provision?

14. Where does the service entrance end?

15. How must the grounded conductor be fastened to the ground bus bar?

16. What is the preferred grounding electrode for the service entrance panelboard?

17. Where are small grounding electrode conductors installed?

18. What means are used to insure all metal parts of the service entrance, the grounded conductor, and the grounding electrode conductor are at the same potential electrically?

**235. State the installation procedures for a three-wire, single-phase, overhead service entrance system.**

The first requirement for installation of the service entrance is to determine the size of the conductors. Conductor size is determined by the planned and anticipated electrical load in the building. This load is based on the need for lighting and small appliances, plus the power to operate heavier equipment, such as dryers, furnaces, and motor-driven equipment. The power requirement for a building is covered in detail in chapter 5, Planning and Laying Out Works. There are also some minimum size requirements for conductors. For instance, the service drop conductors can be either copper or aluminum. Copper service drop conductors must be no smaller than No. 8 AWG. A single-family dwelling requires a three-wire service entrance of at least 100 ampere capacity. Service entrance conductors are usually larger than service drop conductors because of the difference in ampacity permitted conductors are in free air.

*Service mast.* The service entrance conductors may be brought in through rigid metal conduit. This conduit may be installed as a service mast or as just metal conduit. Figure 4-5 shows one method of installing a service mast. The mast is made from a single length of rigid steel conduit with a minimum recommended diameter of 2 inches. It is installed through the roof and may go down inside the wall between the studs. The mast must be strong enough to provide an anchor for the service drop. When the drop is anchored to the mast, it may be as close as 18 inches to the roof as long as it does not pass over more than 4 feet of roof overhang. If the mast is not strong enough as installed, braces or guys are added to provide the necessary support. A roof flashing plate with a neoprene seal is installed over the mast where it comes through the roof to prevent water leakage. A weatherhead is attached to the top of the mast. At the bottom of the mast, fittings are installed to permit mounting of the meter socket and the service disconnect, or just the disconnect if power is not to be metered.

The service mast may be installed so that it comes down the exterior wall of the building. It is anchored to the wall with pipe support clamps that are held in place by bolts extending through the wall. In many cases, screws driven into the siding or some type of screw anchor provide adequate support for the pipe clamps. This method of mounting a service mast still requires the use of a roof flashing plate and neoprene seal to prevent water leakage. The service conductors may also be brought in through rigid metal conduit fitted with a weatherhead and fastened to the building wall but not extending through the roof. The service drop may be anchored to fittings on the service mast or conduit, or it may be fastened to porcelain insulators attached to the building. The method and point of anchorage are influenced by building height, whether a service mast is used, and the available space for the service drop.

*Service disconnect.* The service disconnect may be a separate switch, or it may be combined with a panelboard. Separate switches are contained in surface-mounted boxes. The switchbox is mounted on an inside wall directly behind the service entrance conduit. The conduit may be brought through the wall into the back of the switchbox, as shown in figure 4-6; or it may pass through the wall above the switchbox and enter at the top. The switchbox has knockout plugs. The proper plug must be removed to provide an entry for the conduit. The switchbox can be attached directly to the wall with screws if the wall has a wood facing. Open studs may require that wood framing be built on which to mount the box. Masonry walls, such as concrete or brick, require the use of anchors for mounting purposes. Wooden plugs are banned for this purpose because they are likely to pull loose. After the conduit is attached to the box, a grounding bushing similar to that shown in figure 4-6 must be installed. The bushing may be grounded to the box or it may be connected to the neutral bus bar, depending on the specific installation. NOTE: All conduits must be bushed and grounded that enter or exit the box. Mounting of a combination service disconnect and panelboard is discussed in another objective.

*Service conductors.* The service conductors are insulated wires that run in one continuous length from the service drop to the service disconnect. Splices are not permitted by the NEC. The neutral conductor may be a bare wire when the service conductors are inclosed in a raceway. Where a meter is included as part of the service entrance, the conductors are run from the service drop to the meter socket. A second set of conductors connects the meter socket to the service disnect. Figure 4-7 shows how the service con conductors are wired to a meter mount.

The weatherhead (or service head) should be higher than the point where the service drop is anchored. When this is not possible, the weather head may be placed to the side of,

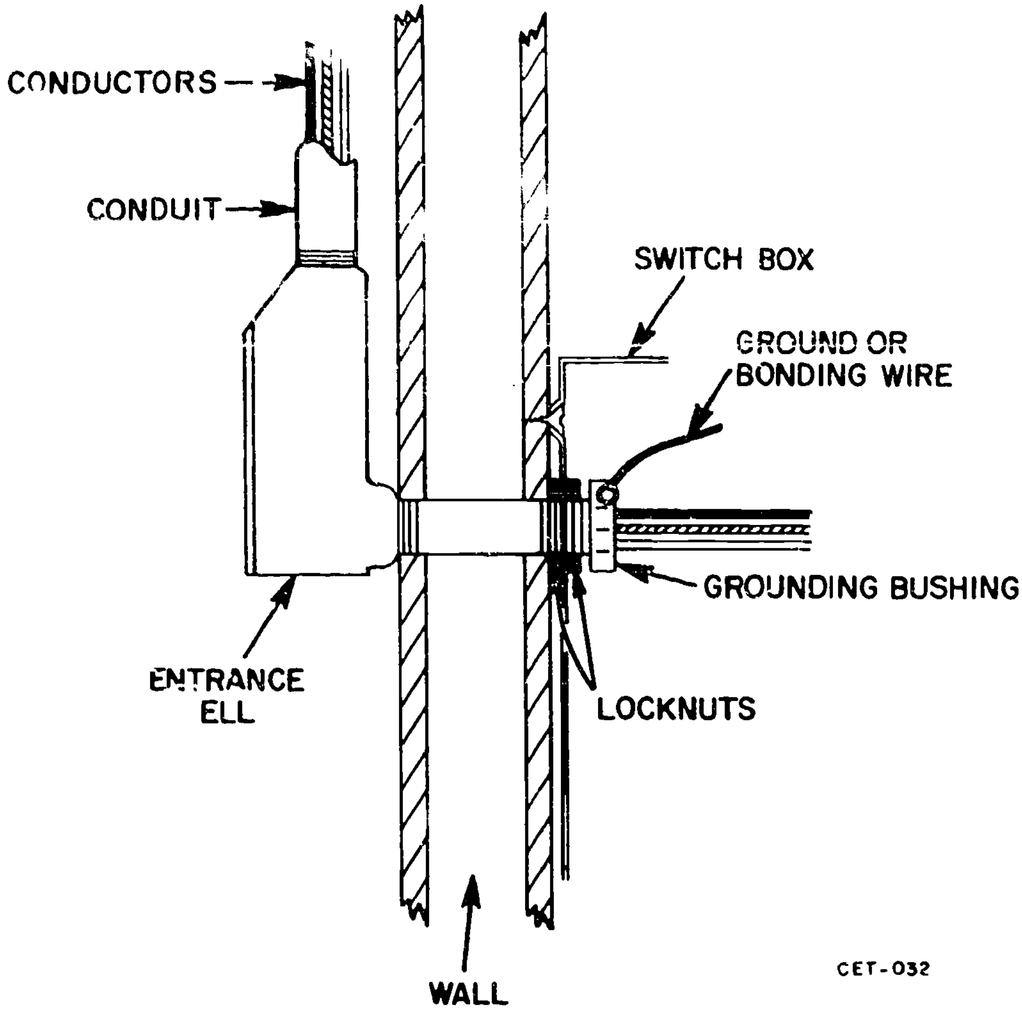



Figure 4-6. Switchbox mounting.

or even below, but not more than 24 inches from the service drop. The service conductors must be long enough to provide drip loops between where they are connected to the service drop and the weatherhead, as shown in figure 4-8. These drip loops prevent water from running into the weatherhead. The service conductors are spliced to the service drop conductors with split bolts or other types of pressure connectors. If the service drop conductors are aluminum, special connectors are needed to prevent electrolytic corrosion from taking place between the aluminum and the copper service conductors. Be sure to get the aluminum conductor in the proper space in these connectors. Tape the connectors and wire ends on the insulated conductors after the splice is complete. Do not bother to tape the neutral if it is a bare wire.

The service conductors that enter the service disconnect must be long enough to connect easily with the switch terminals. The neutral conductor is usually longer since it connects to the neutral bus bar. Terminal lugs are needed on the conductors because of their large size. These are attached by pressure rather than by solder because large solder connections are difficult to make. The grounding of the service entrance is discussed in a later objective.

*Service-entrance (SE) cable*. Service entrance cable can be used for the service entrance in place of rigid conduit where it is not apt to be damaged physically. Service entrance cable has the insulated conductors wrapped with the stranded neutral conductor. This method of wrapping the neutral around the other conductors provides some protection from damage and gives some added stiffness. The service drop end of the SE cable may have a weatherhead attached that protects against moisture. Another means of keeping moisture out is to form a gooseneck on the end of the SE cable like that shown in figure 4-9. This gooseneck must be taped and painted or taped with a self-sealing, weather-resistant thermoplastic. The service entrance cable must be supported by a cable clamp within 12 inches of the weather head, gooseneck, or connection to a raceway. Additional clamps are required for support at intervals no more than 4 ½ feet apart.

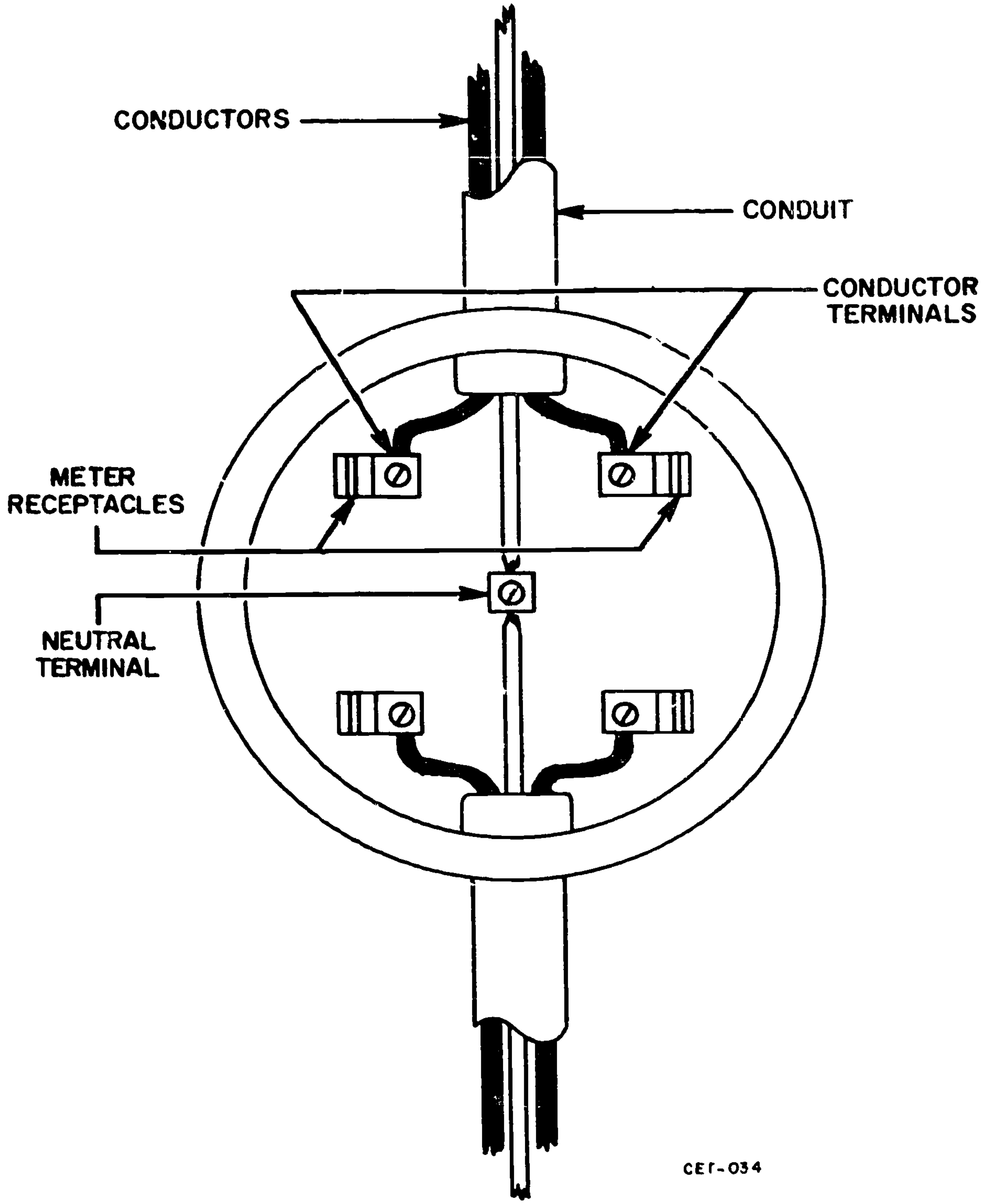



Figure 4–7. Meter mount wiring.

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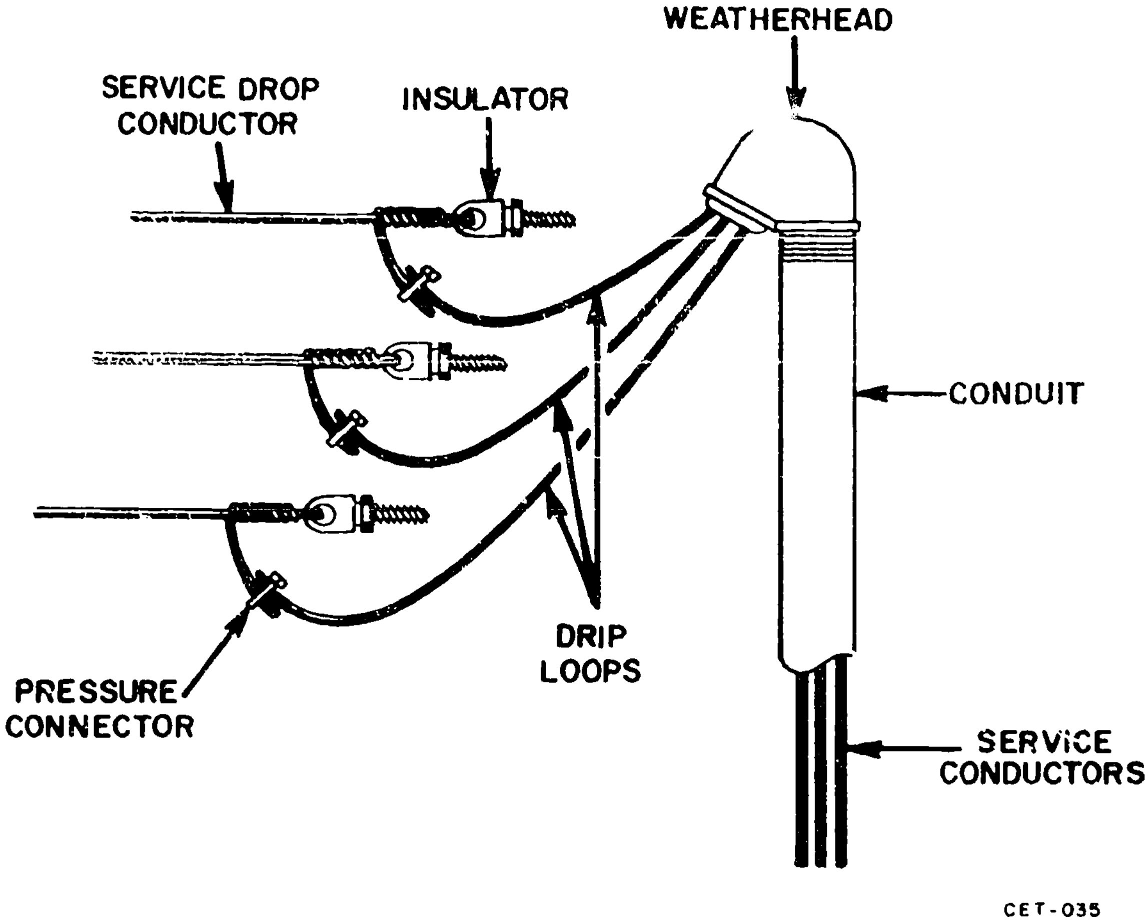


Figure 4-8. Service entrance connections.

The service cable enters the interior of the building through a hole drilled in the exterior wall. A hole is easily bored in a wooden wall either by hand or with a powered drill. A masonry drill or star drill must be used on masonry walls. The hole size is dictated by the size of the entrance cable. The hole should permit the cable to enter without damage but should not be large enough to cause sealing problems. Additional space is required in cases where the grounding electrode conductor comes out through the SE cable entry hole. After the entry cable is inserted through the wall, a wallplate with either a soft rubber gasket or nonhardening sealing compound is screwed to the wall. This plate holds the SE cable in place and provides a weather-proof seal.

**Exercises (235):**

1. What must you determine before installing a service entrance?

2. On what is the amount of power needed for lighting the interior of a building based?

3. What is the minimum amperage requirement for the service entrance of a single-family dwelling?

4. Where would you find information concerning permissible methods of protecting service-entrance conductors?

5. What are the basic requirements for installing a service mast?

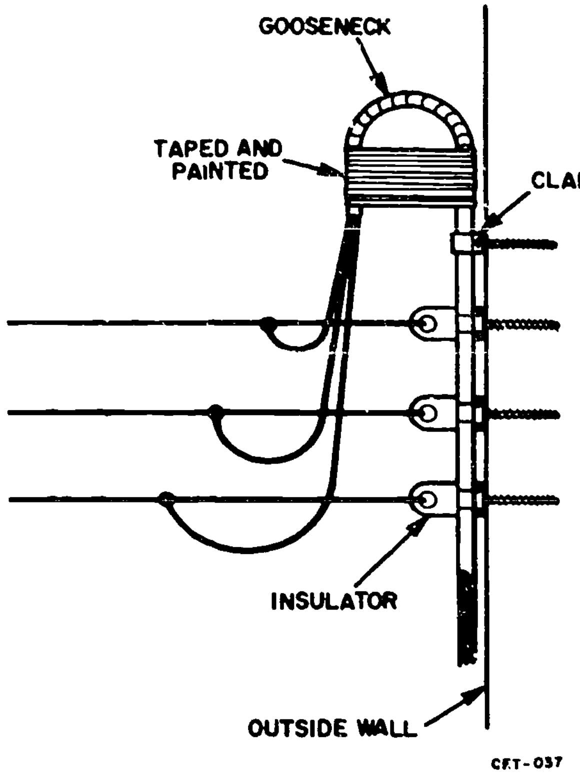


Figure 4-9. Service entrance cable gooseneck.

6. What is the procedure for installing the service disconnect when it is a separate switch?

7. Where is a break in the service-entrance conductors permitted?

8. What is the maximum distance the weatherhead can be located from the service drop?

9. Why are drip loops provided in the service-drop conductors?

10. What precaution must you take when splicing copper-service conductors to aluminum service-drop conductors?

11. How are service conductors connected to the switchbox terminals?

12. Briefly describe the construction of a service-entrance cable.

13. How is moisture kept out of the service drop end of a service entrance cable when a weatherhead is not used?

14. What are the minimum support requirements for service- entrance cable?

15. How is service entrance cable brought from the exterior to the interior of a building?

**236. Identify characteristics of underground service entrance systems, and specify procedures for installing them.**

**Underground Service.** Electrical power may be brought into a building from underground instead of overhead. In fact, underground distribution is becoming more and more common. In a few cases, the distribution system is overhead but the building service is underground. The conductors corresponding to the service drop, and which bring the power to the building, are called the service lateral. These conductors may be tied to an overhead distribution system and then run down the pole and into the ground before they are run to the building. In other cases, the entire distribution system, except for the transformers, is underground. The service lateral may be connected to a secondary main, or, if the building is served by separate transformers, it is connected to the transformers.

The service lateral may be installed in rigid conduit, either metal or nonmetallic. It can also be installed with underground service entrance (USE) cable. Figure 4-10 shows the layout of an underground service to a building. In this illustration, the service lateral runs from the transformer to the terminal box. A terminal box is installed whenever a meter is to be part of the system, the wiring method is changed (e.g., from conduit to cable), or multiple disconnects are to be used. Whenever the service lateral is connected directly to the service equipment (disconnect), the point of connection between the service lateral and the service entrance is considered to be the point of entry to the building. The service lateral can be installed outside the building, and will terminate in either a terminal

box or the service equipment. There are no service-entrance conductors if the service lateral connects directly to the service equipment outside the building.

Underground service laterals must be protected from damage by meeting minimum burial depths. Underground service-entrance cable and other direct-burial cable must be buried at least 24 inches deep. Rigid metal conduit needs to be only 6 inches deep, but rigid nonmetallic conduit approved for direct burial must be 18 inches deep. Underground service entrance cable entering a building from underground must be protected by an approved entrance or raceway from the point of entrance to below the ground line and beyond the outside walls of the building. The rest of an underground service entrance is the same as for an overhead system.

**Exercises (236):**

1. What are the conductors of an underground system that correspond to a service drop called?

2. In which three places may the underground conductors to a building be connected to the power source?

3. What are two methods for installing a service lateral?

4. When is a terminal box used with a service lateral?

5. Where does the service entrance start when the service lateral connects directly to the service equipment inside a building?

6. A service lateral installed in rigid, nonmetallic conduit must be protected with how many inches of dirt?

7. What protection is required for USE cable entering a building from underground?

## 4-3. Distribution Panels

Once power is brought into a building by way of a service entrance, it must be divided and sent out to the points where it is going to be used.

**237. Identify types of distribution panels in terms of their design characteristics.**

A distribution panel, as its name implies, serves as a center or point in the electrical system where the power is fed to the branch circuits. There will be only one distribution panel in a building when the requirement is for lighting and power and the building is not too large. On the other hand, several panels may be required in a large building, or one in which quite a lot of electrically powered equipment is to be operated.

A distribution panel consists mainly of a metal cabinet that houses bus bars and individual circuit protective devices. The protective devices (fuses and circuit breakers) protect the circuits against excessive current flow. Distribution panels may be divided into categories according to the purpose for which the circuits are to be used. They may also be classed according to the type of protective devices used with the panel.

**Purpose and Design of Panels.** Distribution panelboards are classed generally as lighting and appliance panels, power panels, or feeder panels. Any panelboard that has more than 10 percent of its overcurrent devices rated at 30 amperes or less and has provisions for neutral connections is classified as a lighting and appliance panel.

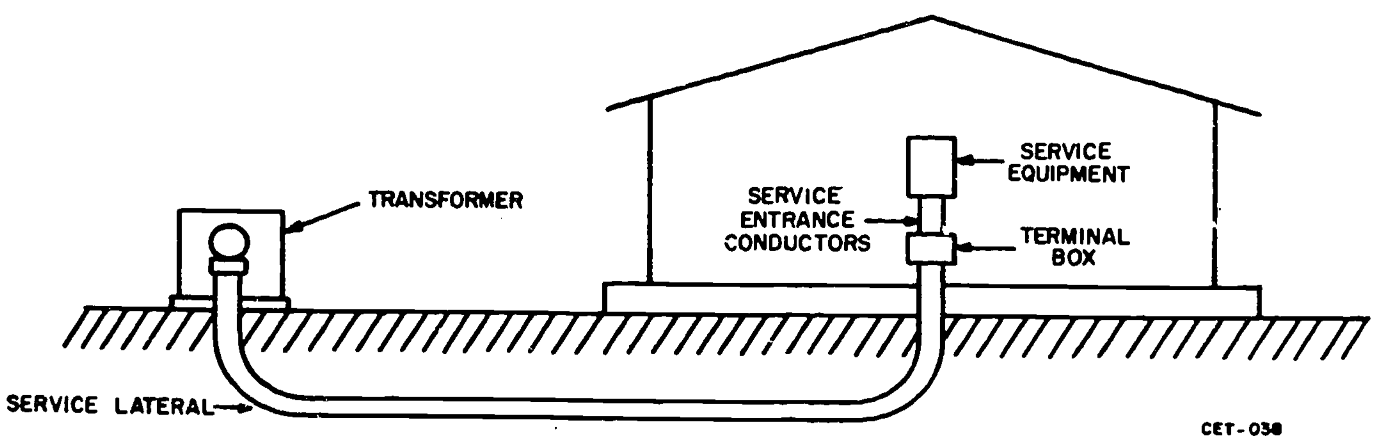


Figure 4-10. Underground service to building.

These panelboards provide connections for branch circuits that are used for both lighting and power purposes. Power panelboards are used mainly to provide power for the operation of electrical equipment. Most of the branch circuits from a power panel will be 240 volts or 480 volts. However, some lighting circuits may be provided. Feeder panelboards may be used to distribute power to other panelboards located at various points in a building. These other panelboards can be either power panels or lighting and appliance panels. These added panelboards allow branch circuits to be installed where they are the most useful, with an overall savings in material.

Panelboards must be rated at least as high as the feeder capacity required for the load. Panelboards are marked by the manufacturer with the voltage, current rating, and number of phases for which they are designed. This information, plus the manufacturer's name or trademark, must not be obstructed by interior parts or wiring after the panelboard is installed. According to the NEC, lighting and appliance panelboards cannot have more than 42 overcurrent devices besides the mains. Two-pole and three-pole circuit breakers are counted as two and three overcurrent devices respectively.

According to the NEC, each lighting and appliance panelboard must be protected from current flow on the supply side by not more than two main circuit breakers or two sets of main fuses having a combined rating no greater than that of the panelboard. This protects not only the feeders, but also the panelboard bus bars. The panelboard does not need individual protection if the panelboard feeder has overcurrent protection no higher than the panelboard rating. The total load on any single overcurrent device in a panelboard must not exceed 80 percent of its capacity where, in normal use, the load continues for 3 hours or longer to prevent overheating of the conductor.

Panelboard cabinets must be grounded. A terminal bar must be provided for attachment of feeder- and branch-circuit equipment-grounding conductors where nonmetallic raceway or cable is used. This terminal bar must be bonded to the cabinet, but not to the neutral bar except in service equipment.

Three-phase panelboards supplied by a four-wire, delta-connected system that has the midpoint of one phase grounded must have the higher voltage phase-to-ground conductor or bus bar marked. This high-voltage conductor should have an orange outer finish or be tagged clearly. The identification is required at any point where a connection can be made and the neutral conductor is also present. The phase arrangement on a three-phase panelboard is A, B, C, from left to right, or top to bottom when viewed from the front. The B phase will be the phase that has the higher phase-to-ground voltage.

*Fuse Panels*. Fuse panels, as the name implies, contain fuses for protection of each circuit. You will find that there are many designs of fuse panels. These designs vary in size, capacity (amperage and voltage), and type of installed fuses. The capacity of the panel is based on the ampacity of the panel's bus bars. The number of bus bars is determined by whether it is a single-phase or three-phase panel. This type of panel may be either surface or flush mounted. The cabinet or case has knockouts so that conduit or cable connectors can be attached directly to it. Panels supplying power to general branch circuits must be of the dead front design. This means that when the door on the panel is open, no live parts are exposed. You must remove the cover from the panel to gain access to the interior parts.

Fuse panels are designed for plug fuses, cartridge fuses, knife-blade fuses, or a combination of these. Fuse panels that use an Edison base fuse are called a plug fuse panel. These fuse panels are not to be installed either for new work or as a replacement panel unless they have been modified to accept type S fuses. (Adapters that will accept only type S fuses are installed in the fuse holders.) Type S plug fuse panels that don't need adapters are available also. Cartridge fuse panels use either the ferrule or knife-blade type fuses, depending on the capacity of the panel. All the fuses listed here will be covered in the section on protective devices.

*Circuit breaker panels*. Circuit breaker panels serve the same purpose as fuse panels. Generally, they resemble fuse panels except for the protective devices used in the circuits.

Circuit-breaker panels are preferred to fuse panels because a circuit breaker needs only to be reset after it is tripped by an overload condition. Fuses, on the other hand, must be replaced after they are blown. An added convenience of the circuit breaker is that it can be used as a switch to manually disconnect a circuit from its power sources. Circuit breaker panels must be of the dead front design the same as fuse panels. Replacement of individual circuit breakers requires that the front cover be removed.

**Exercises (237):**

1. How many distribution panels would be installed in a three-bedroom, military family housing unit?

2. Name three types of distribution panels.

3. What is a lighting and appliance panelboard?

4. What is the purpose of a power panelboard?

5. What type of panelboard is set up to furnish power to other panelboards?

6. For what reason does a panelboard furnish power to other panelboards?

7. What information must appear on a panelboard?

8. What protection from current flow must be provided a panelboard?

9. What are the grounding requirements for panelboards where wiring is done with nonmetallic cable?

10. How is the high-voltage conductor of a four-wire, delta-connected system with the midpoint of one phase grounded identified?

11. On what is the capacity of a fuse panel based?

12. A three-phase fuse panel has a total of how many bus bars?

13. What is a dead front fuse panel?

14. What are three types of fuses used in fuse panels?

15. Explain the conditions under which an Edison base fuse panel can be installed.

16. What is the main advantage of a circuit-breaker panel over a fuse panel?

17. Why are breaker panels preferred for use over fuse panels?

**238. State the procedures for installing distribution panels, and calculate for an unbalanced load.**

As previously mentioned, the distribution panel distributes electrical energy to branch circuits through its circuit breakers or fuses. It is supplied with power from the main disconnect switch. Power is fed from the main switch to the distribution panel by conductors run in conduit or by service entrance cable. In some cases, the main disconnect switch is combined with the distribution panelboard. This arrangement permits the service conductors to be connected directly to the panelboard, eliminating the need for a separate switch box and the interconnecting wiring.

**Panelboard Selection.** One of the first requirements for installing a panelboard is to select one that provides an adequate number of spaces for the circuits to be installed. The number of required circuits is determined by the size of the building and the equipment to be used in it. A panelboard is usually selected that provides at least one unused overcurrent protective device when only a few circuits are installed. When a good many circuits are installed, it is common practice to leave two or more unused spaces for future expansion. The cabinet furnished with the panelboard normally provides adequate space for wiring at the sides to meet code requirements. In an unusual case, it may be necessary to use a larger cabinet to provide required wiring space.

**Cabinet Installation.** Cabinets may be either surface mounted or flush mounted. Surface-mounted cabinets are used mostly with exposed wiring. When wiring is concealed, a flush-mounted cabinet is needed. Cabinets installed in damp locations must have at least 1/4-inch airspace around the cabinet to allow for air circulation. Under normal conditions, interior parts are removed from cabinets before they are mounted. A surface-mounted cabinet is attached to the wall with screws, hollow wall fasteners, or masonry anchors. Spacers are placed behind the cabinet, if needed. A cabinet that is to be flush-mounted on a frame wall may need to have framing added. In walls built of concrete, tile, or other noncombustible material, cabinets can be recessed with the front edge up to 1/4 inch from the finished surface. Cabinets in wood or other combustible walls must either be flush or project from the surface.

After the cabinet is mounted, the wiring for the circuits should be installed. Circuit wiring may be run in conduit, or nonmetallic cable may be used. Most circuits enter the cabinet through a hole made by removing the correct knockout plug. No more knockout plugs should be removed from the cabinet than are needed for the circuits being put in. If a knockout is removed and the hole is not used, the hole must be reclosed with a plug or plate that affords protection about equal to that afforded by the cabinet walls. When conduit is used, it is attached directly to the cabinet with conduit fittings. The end of the conduit must be bushed to provide a smooth, nonabrasive surface for the conductors. Insulated bushings are required for ungrounded No. 4 and larger conductors. Nonmetallic cable is brought into the cabinet through nonmetallic cable connectors attached to the cabinet. Regardless of the wiring method, the ends of the conductors brought into the

cabinet should be left long enough to allow any conductor to be connected at any point within the cabinet.

**Panelboard Connections.** Once the circuits have all been brought into the cabinet, the panelboard can be mounted in the cabinet. Also, the neutral bar and the equipment ground bar are attached to the cabinet. The ground bar must be bonded to the cabinet by either a bonding jumper or the more common method of running a screw through the bar into the cabinet. The equipment ground bar and the neutral bar are not bonded together unless the panelboard also serves as the service equipment

Quite often the panelboard is not connected until the interior wiring is done and the receptacles, switches, and fixtures have been installed The method of attaching circuit conductors is based on conductor size and type of terminals on the panelboard. Small conductors, No. 10 and smaller, normally are looped around a screw-type terminal. Larger conductors may need to have terminal lugs attached so that connections can be made to screw terminals. Pressure-type terminals are often provided for larger conductors, neutral conductors, and equipment grounding conductors.

Conductors should be connected in a neat and professional manner. In many cases, conductors are connected with little excess wire. Conductors brought in through the sides of the cabinet are connected directly to the overcurrent device. Those brought in from the top or bottom of the cabinet are neatly bent to a 90° angle opposite the fuse or circuit breaker to which they are to be attached and are cut just long enough to make a good connection. However, many experienced electricians feel that this system of connecting conductors is not necessarily the best, even though it presents the most uncluttered look and leaves more space around each conductor. These electricians usually try to leave an end on each conductor that is equal to the height plus the width of the cabinet. Each conductor is run along the panel and looped back 180° before being connected to its fuse or circuit breaker. Little added material is needed and the extra length on the conductor permits it to be switched to another terminal on the panel if desired. Also, in case of conductor breakage near the terminal, the conductor can be reconnected easily.

The ungrounded conductors in a fuse panelboard are connected directly to terminals on the bus bars. In a circuit breaker panelboard, the ungrounded conductors are usually connected to the circuit breaker. The circuit breaker then is inserted in the panelboard. In most cases the breaker is snapped into place and is held by spring tension. Sometimes breakers are held in the panelboard by screws.

**Load Balancing.** Conductors cannot be connected to a panelboard by attaching each one as you come to it. The arrangement or sequence of attaching conductors to the panelboard is determined by the arrangement of the bus bars in the panelboard, whether the circuits are 240 volts or 120 volts, and the need to balance the load on the phase conductors. Bus bars are installed into panelboards in one of several ways. Most of the time, the bus bars are run in a vertical configuration. In one arrangement, a split-bus panelboard is used that has all the 240-volt circuits in the upper section and the 120-volt circuits in a lower section. Another type of split-bus panelboard uses one main circuit breaker to feed one set of branch circuits and a second main circuit breaker to feed a second set. In many cases, panelboards are designed so that any two adjacent terminals can be used to provide 240-volt service. This arrangement also means that two 120-volt circuits attached to adjacent terminals are connected to different phase conductors. Since there are so many panelboard layouts, you must look at the panelboard to see how it is set up for 240-volt service, and you must be sure you get the conductors for 240-volt circuits connected to the proper terminals.

Loads connected to a panelboard should be divided as evenly as possible between the supply conductors. This process of equalizing the load is commonly referred to as load balancing. The purpose of load balancing is to reduce voltage drops that result from overloading one side of the incoming service. It also prevents the possibility of overloading the neutral. A perfectly balanced load between the supply conductors reduces current flow in the neutral to zero.

Load balancing is no problem for 240-volt circuits on a three-wire, single-phase system, since the load has to be equal on each phase conductor. However, the 120-volt circuits are a different matter. These must be connected in such a way that the loads tend to equalize. Generally speaking, the simplest way to balance the load on a panelboard is to connect an equal number of branch circuits to each phase conductor. But this method does not necessarily give you a balanced load.

The indiscriminate connection of branch circuits without considering their loads can cause you to end up with an unbalanced condition. Suppose we had a 240-volt, 1$\phi$, 3-wire system. A phase has a total of nine circuits connected. B phase has 11 circuits connected. Checking the phases with a clamp on ammeter, we find A phase reads 25 amps and B phase reads 35 amps. The 10 amp difference will be found on the neutral. If we read each circuit on B phase and find one approximately 5 amps, we could swap that circuit to A phase. This should give A phase 30 amps, B phase 30 amps, and eliminate any current on the neutral. Most of the time, you should be able to connect half of the lighting circuits and half of the appliance circuits to each phase conductor to give you a reasonably well-balanced load. Spare circuits should also be equalized. There is one more thing to consider: If there are appliance circuits where the loads are known to be heavy, these circuits must be divided between the phase conductors.

**Exercises (238):**

1. What is the basis upon which a panelboard is selected for installation in a building?

2. Why should unused spaces be left when a panelboard is installed?

3. What usually determines whether a surface-mounted or flush mounted cabinet will be used?

4. What are the space requirements for mounting panelboard cabinets in damp locations?

5. What is the procedure for installing a flush-mounted cabinet in a masonry wall?

6. What action is required if a cabinet knockout is removed and then not used?

7. How are No. 3 conductors protected from damage when brought into the cabinet from metal conduits?

8. What is the general rule for determining the length of conductor ends brought into a panelboard cabinet?

9. How is electrical continuity attained between the equipment ground bar and the panelboard cabinet?

10. When are the equipment ground bar and the neutral bar bonded together?

11. How are No. 12 conductors usually connected to a panelboard?

12. With what is a No. 8 conductor connected to a panelboard?

13. What are pressure-type terminals often used in panelboard cabinets to connect?

14. How can conductors be connected to a panelboard that will permit repositioning or repair if broken?

15. To what do most circuit breaker panelboards have the ungrounded conductors connected?

16. What are the factors that influence the sequence for connecting conductors to a panelboard?

17. What type of panelboard has all 240-volt circuits in one section and all 120-volt circuits in another section?

18. A panelboard that is set up so that any two adjacent terminals provide 240-volt service will also result in what?

19. What is load balancing?

20. What is the purpose of load balancing?

21. What is the neutral load on a 240-volt, $1\phi$ panel when A phase equals 65 amperes and B phase equals 39 amperes?

22. What is A phase amperes on a 240-volt, $1\phi$ panel when B phase equals 75 amperes and the neutral equals 15 amperes?

### 4-4. Protective Devices

Before branch circuits can be hooked up to a panelboard, the protective devices, in the form of fuses and circuit breakers, must be selected. These protective devices, as the name implies, provide protection for the circuit conductors and equipment that may be connected to the circuit.

**239. Identify the types and ratings of protective devices, and specify installation requirements and limitations.**

**Plug Fuses.** Plug fuses of the Edison-base type screw into sockets similar to an ordinary light socket. Plug fuses are used from 0 to 30 amperes at a maximum of 125 volts. Plug fuses have a clear glass or mica window directly over the fuse element. This window provides a means for determining visually whether the fuse is good or blown. Fuses rated from 0 through 15 amperes have a hexagonal window, while those rated from 16 through 30 amperes have a round window. Plug fuses must be screwed in firmly f good contact, but not tight enough to make them difficult to remove. Edison base fuses may be used only for replacements in existing installations.

Plug fuse panels to be used in new work must be modified so that the type S fuse must be used. Type S plug fuses require an adapter. The adapter is designed so that once it is screwed into place, it cannot be removed. Type S fuses and adapters come in three capacity ranges: 0 through 15 amperes, 16 through 20 amperes, and 21 through 30 amperes. The advantage to this system is that fuses of a larger ampere rating will not fit into an adapter of a lower ampere capacity range. In addition, this prevents objects, such as pennies and wire, from being inserted into the socket to override the protection.

**Cartridge Fuses.** Cartridge fuses are of two types— the ferrule and the knife-blade types. Both types are available with replacement or nonreplaceable fuse links. Ferrule-type fuses are available in ampere ratings from 0 through 60. Fuse panels that use ferrule-type fuses have specially designed fuse clips in which only ferrule types will fit. Fuse diameter and length increase as amperage and voltage increase. Ferrule-type fuses are used in circuits up to 600 volts.

Fuse panels that provide distribution for high capacity circuits use knife-blade fuses for protection. The fuse clips are designed especially to receive knife-blade fuses only. Knife-blade fuses are available in ampere ratings of 61 through 6000. The maximum voltage rating for knife-blade fuses is 600 volts.

Two factors must be considered when selecting fuses for circuit protection. These are the total current flow and the voltage of the circuit in which the fuse is to be installed. Since the purpose of the fuse is to protect the circuit, it must be the weakest point in the circuit. Thus, the fuse used should be rated no higher than the lowest-rated component to be protected. Before installing a fuse in a panel, check the condition of the fuse holder or clips. These must be clean and hold the fuse firmly.

**Circuit Breakers.** One of the newer types of protective devices, used more often than fuses because of the way it reacts to an overload, is the circuit breaker. A circuit breaker trips on an overload, but can be reset to complete the circuit again without having to be removed or replaced. Circuit breakers are classed according to their operating principle. They may be thermal, magnetic, or combination thermal-magnetic. Circuit breakers may be ordered with one, two, and three poles. Multipole breakers are designed to open all ungrounded conductors in a circuit at the same time.

A thermal-type circuit breaker has a bimetallic element within the breaker that responds to temperature change. The bimetallic element is made by fusing together two strips of dissimilar metal. Each strip has a different expansion rate when heated. Current flowing through the breaker generates heat, which increases as the flow increases. The heat causes the bimetallic element to bend and act against a latch. The breaker mechanism is adjusted so that when the current flow reaches a set level, the element bends enough to trip the latch. This action opens a set of contacts to break the circuit. The thermal-type circuit breaker commonly is called a time lag breaker because the breaker does not open immediately when an overload occurs. The bimetallic element requires a short time (length depends on the size of the overload) to respond to the heat generated by the overload current.

A magnetic-type circuit breaker responds instantaneously when an excess of current flows through the breaker. A small electromagnet is used to actuate the breaker mechanism. Whenever a predetermined amount of current flows through the electromagnet, enough magnetic flux is created to attract a small armature. As the armature moves, the breaker mechanism trips and opens the circuit.

The thermal-magnetic circuit breaker, as the name implies, combines the features of both the thermal and the magnetic types. Of the three, the thermal-magnetic circuit breaker is preferred for general use. A small overload actuates the bimetallic strip to open the circuit on a time delay, while a large overload or short circuit actuates the magnetic trip to open the circuit instantly. Circuit breakers are rated in amperes and volts the same as fuses, and you select them on the same basis. Circuit breakers are sealed units and no attempt should be made to adjust the ampere capacity or to repair it. A defective breaker must be removed and replaced.

Circuit breakers that are to be used in circuits that may pose an added hazard to the user are made with an extra safety feature. This breaker is called a ground fault circuit interrupter (GFCI). It is a thermal-magnetic breaker with an additional internal circuit that detects a current leak from the hot wire to ground and opens the breaker if that current reaches a set amount. This leakage cannot be more than 5 (+1) milliamperes (thousandths of an ampere) to ground. Most of these breakers have a test button that can be used to check the GFCI to see whether it will trip when there is a fault. Figure 4-11 shows a GFCI installed. You connect the circuit hot wire to the breaker the same as you do on a standard breaker. The circuit neutral is connected to another terminal on the GFCI instead of to the neutral bar in the panel. The GFCI comes with an attached white neutral wire, which you then connect to the neutral bar. The NEC requires that GFCIs be installed for several circuits used in the home. These circuits include ALL 120-volt, single-phase, 15- and 20-ampere receptacles in bathrooms, garages, and outdoors. GFCIs may be used elsewhere when there is a need for the added protection.

**Exercises (239):**

1. Name the two types of plug fuses.

2. What are the limitations on using Edison base fuses?

3. List the amperage ratings for type S plug fuses.

4. What is the maximum capacity of amperes for ferrule-type cartridge fuses?

5. Why can't a 60-ampere, ferrule type be used in place of a 20-ampere, ferrule type?

6. What is the weakest part of an electrical circuit?

7. How does a thermal-type circuit breaker work to interrupt the circuit on an overload?

8. How does a magnetic type circuit breaker open the circuit on an overload?

9. What is the advantage of a magnetic circuit breaker over a thermal type?

10. What is the purpose of a GFCI?

11. Where must ground fault breakers be installed in a home?

## 4-5. Grounding

An electrical system must provide for the protection of life and property when faults develop from system breakdown, lightning, and failure of equipment and appliances connected to the system. Consequently, all metal parts and inclosures of the wiring system plus the neutral conductors must be tied together and then grounded to earth to reduce the electrical potential to zero. Electrical grounding consists of two types: system grounding and equipment grounding.

**240. Specify the types and purposes of electrical grounds, and cite standards for determining their size.**

**System Grounding.** System grounding consists of connecting the neutral conductor to the earth. The purpose of this connection is to get rid of any high voltages that inadvertently enter the system from lightning strikes, a breakdown in transformer insulation, or accidental contact between the service drop and the nearby high-voltage lines. Such voltages are often in the range of 12,000 volts. This voltage is high enough to break down the insulation on system wiring if the system is not grounded. On an ungrounded system, a breakdown of insulation can result in heat generation, which will set fire to any surrounding flammable material. Also, if these high voltages do not find a way to reach ground, and remain on the line, they present a serious shock hazard.

When the system is grounded properly through an adequately sized low-resistance conductor, these high-voltage currents are bled off to the earth immediately. As a result, the danger of fire or shock is reduced to a minimum. Figure 4-12 shows how the system ground is hooked up to the service entrance. The size of the system grounding conductor is based on the size of the service conductors. On a normal installation, service conductors No. 2 or smaller need a No. 8 grounding conductor. The NEC specifies the size conductor to be used with various sizes of service conductors, but in no case may it be smaller than 12 ½ percent of the area of the largest service conductor.

**Equipment Grounding.** Equipment grounding consists of connecting all exposed noncurrent-carrying metal parts of the electrical system to the earth. This includes conduit or other raceways, outlet boxes, switch and panelboard inclosures, and electrical equipment with exposed metal parts. Grounding reduces the possibility of shock or injury to people in case a live conductor contacts any of these conductive parts. Take another look at figure 4-12. As you can see, the metal conduits entering the inclosure are bonded together. These conduits are then bonded to the grounding bus bar. The conduit entering at the right of the inclosure also serves as an equipment-grounding conductor for the rest of the electrical system. The bonding jumper from the grounding bus bar to this conduit grounds the service entrance conduit, in addition to being an equipment ground. Bonding jumpers are made of copper. Those that bond service equipment are sized the same as the grounding electrode conductor. The bonds used for equipment grounding are sized the same as the equipment grounding conductors.

**Exercises (240):**

1. Why are all noncurrent-carrying metal parts of an electrical system, plus the neutral conductors, tied together and grounded to earth?

2. What are the types of electrical grounding?

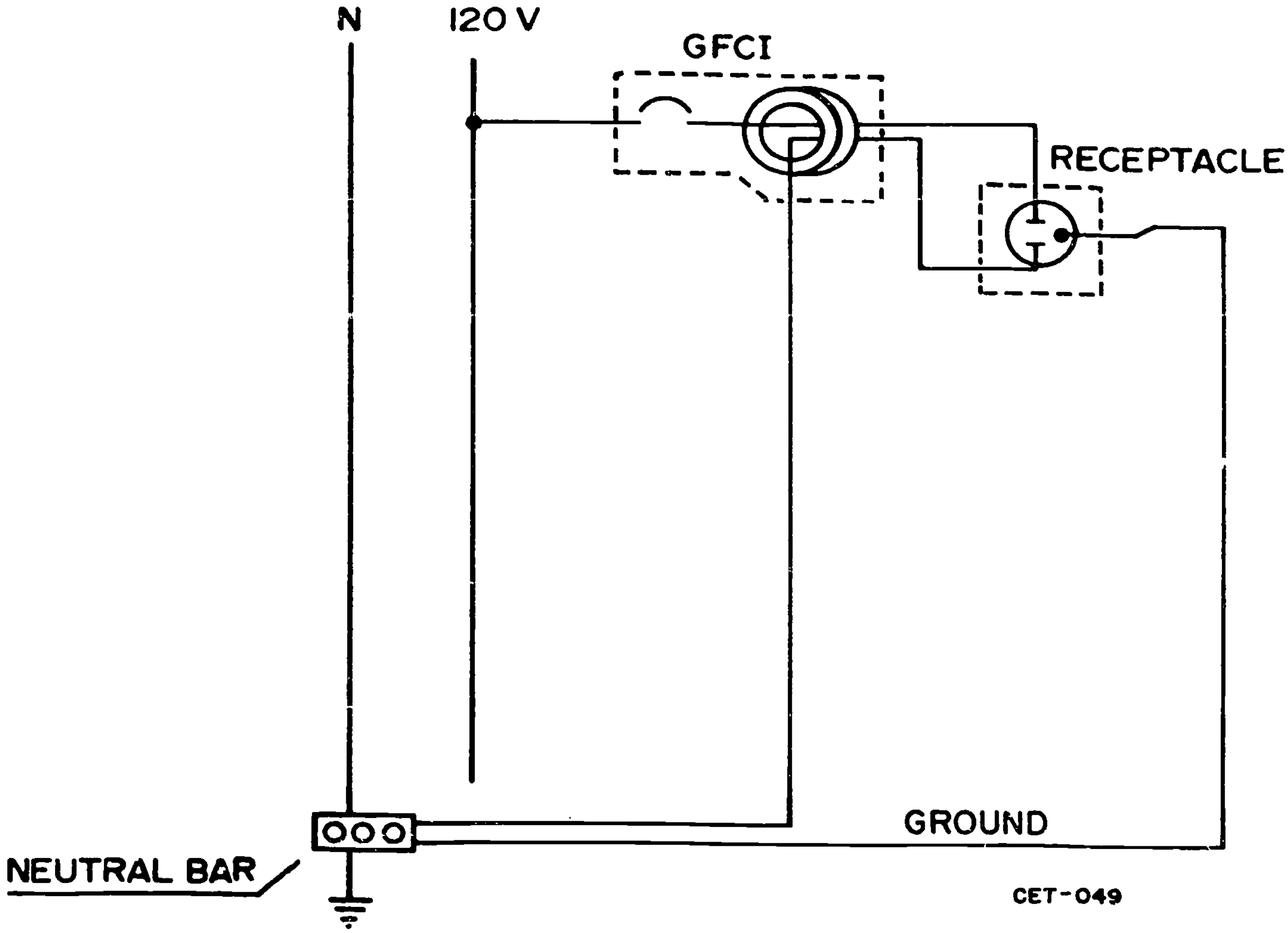


Figure 4-11. GFCI installation.

3. What could happen to an electrical system without a ground that accidentally comes in contact with high voltage?

4. How is the size of the grounding conductor to be used on an electrical system determined?

5. What number grounding conductor does a No. 4 service conductor require?

6. List the parts of the electrical system that are connected together to provide equipment grounding.

7. What is the purpose of equipment grounding?

8. What connects the metal conduits entering the service inclosure to the grounding bus bar?

9. How is the size of bonding jumpers used for equipment grounding determined?

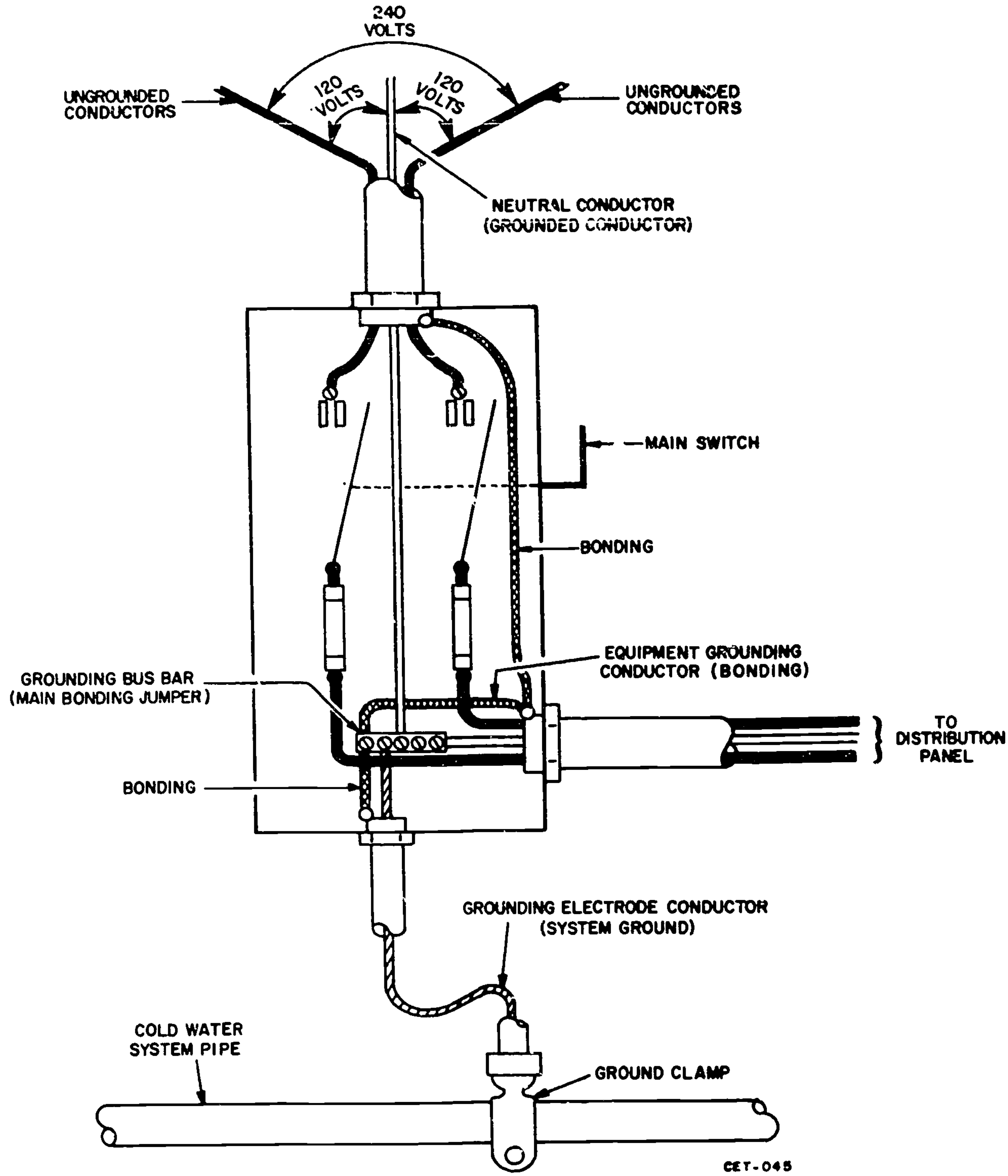


Figure 4-12. System grounding.

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**241. Specify installation procedures for system and equipment grounds.**

**System Grounds.** An effective ground for an electrical system must provide continuity, adequate capacity, and permanence. The NEC specifies the types of grounding electrode systems that meet all of these requirements.

*Normal ground electrodes.* When available, a metal underground water pipe that has direct contact of 10 feet or more with the earth serves as the primary grounding electrode. If the piping system contains a water meter, insulated joints, or nonmetallic sections, bonding jumpers have to be installed around these units to insure continuity. The underground water pipe must be supplemented with at least one other grounding electrode. This added electrode can be an effectively grounded metal frame of a building, a steel reinforcing bar in the bottom of a concrete foundation or footing, at least 20 feet of No. 4 or larger solid copper conductor buried 2½ feet deep; or a made electrode. The two electrodes are bonded together so they will have the same ground potential.

*Alternate ground electrodes.* When the above electrode system is not available for grounding, one or more other electrodes may be used. These may be some type of installed system or a made electrode. One usable system is a metal underground gas piping system that does not have insulating sections or joints or nonconductive coating, if its use is permitted by the gas supplier. Also, other metal underground systems or structures, such as a heating system or an underground tank, make suitable electrodes.

*Made electrodes.* Electrodes can be made from pipe, rods, or plates. Pipe or conduit should be 3/4 inch or more in diameter, and galvanized, if made of iron or steel. Steelrod electrodes should be 5/8 inch or larger in diameter. Nonferrous rods can be as small as 1/2 inch in diameter. A rod with a star-shaped cross section is preferable to a round rod because it is stiffer for the same cross-sectional area. It also provides a much larger contact surface with the soil. When metal plates are used for electrodes, they should have at least 2 square feet of area exposed to the earth. Steel plates should be at least 1/4 inch thick, while nonferrous plates can be as thin as 0.06 inch.

Pipe or rod electrodes should be driven to a depth of 8 feet unless underlying rock interferes. A driving point should be used on the end of the pipe to ease driving. A protective cap will prevent damage to the pipe top from the sledge hammer. When rock is less than 4 feet deep, a trench must be dug to below permanent moisture level and at least 8 feet of electrode buried in it. Plate electrodes need to be buried below permanent moisture level, which normally means at least 2½ feet deep. Where soils are corrosive, electrodes made of copper or other corrosion resistant metal should be used. The durability of galvanized steel is too unpredictable to use under such conditions. Paint lacquer, paraffin, or other protective coatings must be removed from electrodes before they are installed.

*Ground electrode resistance.* After ground electrodes have been selected or installed, a check for resistance should be made. A reasonably accurate check can be performed by connecting an ohmmeter between the electrodes to be used and taking a reading of the resistance. When a single made electrode is to be checked, drive a second ground rod 6 feet from the made electrode and take an ohmmeter reading between them. The resistance between the electrodes and the earth must be 25 ohms or less. A resistance higher than this requires the installation of one or more added electrodes to bring the resistance down. Any added electrodes must be 6 feet or more from the existing electrodes.

*Grounding electrode conductor.* The grounding electrode conductor connects the grounding bus bar of the service equipment with the grounding electrode. The grounding electrode conductor may be of copper, aluminum, or copper-clad aluminum. It must be resistant to any existing corrosive condition. This conductor can be solid or stranded; insulated, covered, or bare; and must not have any joints or splices. The grounding electrode conductor has to have a protective covering, such as metal conduit or cable armor if it is smaller than No. 6. A No. 6 conductor can be installed without a protective cover, provided it is fastened rigidly to the construction and is not subject to damage. No. 4 and larger conductors do not need a protective covering unless they are installed where severe damage may occur. The grounding electrode conductor must be anchored firmly to the grounding electrode. One method is by use of a clamp assembly. One type of these clamps, as shown in figure 4-13, is designed for use with rigid conduit. Any paint, wax, or other nonconductive material must be removed completely before the clamp is installed onto the grounding electrode. Make sure that both the protective covering and the grounding electrode conductors are attached securely to the grounding clamp.

Protective metal inclosures for grounding electrode conductors must be electrically continuous from the service-equipment cabinet to the grounding electrode. A break in the protective covering requires each end of the break to be bonded to the grounding conductor. Solder is

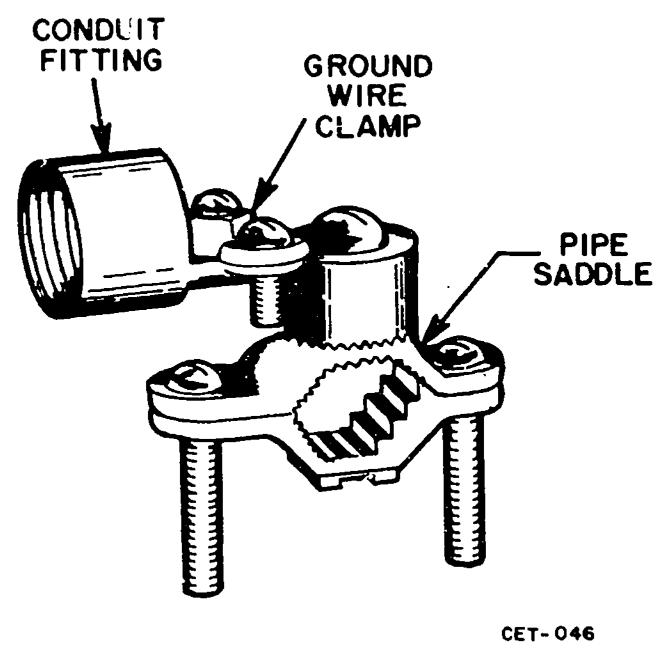



Figure 4-13. Grounding electrode clamp assembly.

not to be used to make any connection in an electrical grounding system. Aluminum or copper-clad aluminum grounding conductors may not be installed in direct contact with a masonry surface, the earth, or where corrosive conditions exist. Also, these conductors, when used outside, may not be installed closer than 18 inches to the earth.

**Equipment Grounds.** Equipment-grounding conductors may be made of copper or other corrosion-resistant material; solid or stranded, insulated, covered, or bare. This conductor can be wire, any shape bus bar, any form of metallic conduit, armor of armored cable, or any other type of raceway approved for the purpose. Equipment-grounding conductors of the preceding types must be installed with approved fittings and terminations tightened with suitable tools. A separate grounding conductor is required in nonmetallic cable and may be run with other conductors in a raceway.

Bare equipment-grounding conductors are permitted and need no further identification. Covered or insulated grounding conductors should be green or green with one or more yellow stripes. Conductors with other than a green finish used as equipment grounds must have the covering stripped at eve accessible point or the exposed covering must be colored green or have green colored tape or adhesive labels applied.

**Exercises (241):**

1. What is the first choice for a ground electrode for an electrical system?

2. What action is required when an underground water pipe has insulated joints?

3. What are the minimum requirements for an adequate ground electrode when an underground water pipe is used as the basic electrode?

4. What may be used as a suitable grounding electrode when an underground water-pipe system is not available in a building?

5. List the materials with their corresponding minimum size that can be used for made electrodes.

6. Describe installation of a steel rod electrode in an area where rock is encountered at a depth of 42 inches.

7. What type of material is needed for made electrodes where installed in corrosive soils?

8. What should you check for after ground electrodes have been selected or installed?

9. How can you determine if grounding electrodes provide adequate grounding after installation?

10. What action is required, if any, when you get a reading of 40 ohms when checking the ground electrode?

11. To what part of the electrical system must the grounding electrode be connected?

12. Describe the physical characteristics of conductors which may be used for grounding electrode conductors.

13. Explain the installation requirements for the grounding electrode conductor.

14. What action must be taken if the protective covering on a grounding electrode conductor will not extend for its full length?

15. What type of grounding electrode conductor must be used where it will be fastened to a concrete wall for a portion of its length?

16. A grounding electrode protrudes from the ground about 9 or 10 inches. What type of conductor will be used as a grounding electrode conductor?

17. State the main requirement for an equipment ground conductor.

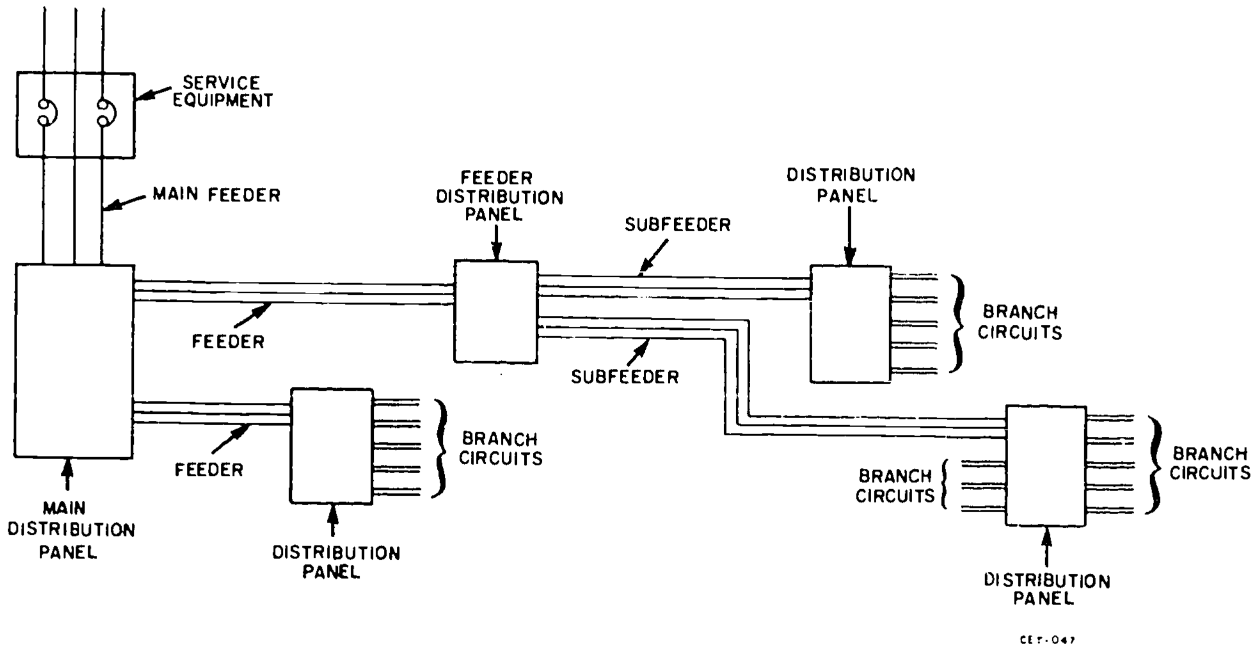



Figure 4-14. Feeder arrangement.

18. What is used to ground equipment when wiring is done with nonmetallic cable?

19. An equipment ground is to be installed using a black insulated wire. Specify two ways this conductor can be identified as an equipment ground.

## 4-6. Branch and Feeder Circuits

Depending upon a building's size, configuration, and its power requirements, a number of branch and feeder circuits may be needed to deliver power to the various fixtures and equipment that are to be installed. In this section, we discuss the purpose of these circuits and how they are installed.

**242. State the purpose of branch and feeder circuits, and list the methods approved for their installation.**

**Purpose.** Electrical circuits installed in a building are either branch circuits or feeder circuits. Branch circuits run between the final overcurrent devices and the outlets for connecting electrically operated equipment. Feeder circuits might be described as those that deliver power to the final overcurrent devices.

**Installation Methods.** Small buildings usually have one main distribution panelboard to which the branch circuits are connected. When the distribution panel is combined with the service equipment, there is no need for a feeder circuit. However, when the distribution panel is separate, a feeder circuit is needed to get power from the service equipment to the distribution panel.

Larger buildings require more than one panelboard to meet their power needs. Feeder circuits are installed to supply power from the main panelboard to panelboards installed elsewhere in the building, as shown in figure 4-14. Although the main panelboard may be used for both branch circuits and feeder circuits it is usually limited to feeder circuits. A separate panelboard (located near the main panelboard) for needed branch circuits is normally preferred to dual usage. Most of the panelboards served by a feeder circuit are used for branch circuits. In some cases, a panelboard at the end of a feeder circuit becomes a junction point to which subfeeders are attached. These subfeeders, in turn, supply branch circuit panelboards. Consequently, through the installation of feeder circuits, it is possible to use a single set of large conductors to replace several long- length small conductors that are required when all branch circuits connect to the main entrance panelboard. Feeder circuits allow panelboards to be located so that the wiring needed for branch circuits is greatly reduced. Generally, such circuit arrangements reduce voltage loss in the conductors and save material and labor.

Branch and feeder circuits may be installed by any method approved by the NEC for the installation of electrical circuits. The main objective is that circuits be

installed to keep troubles and hazards at a minimum consistent with existing conditions. Nonmetallic cable commonly is used for circuits where they are not subject to damage or excessive dampness. Circuits may also be installed in metal raceways, rigid nonmetallic raceways, and cable trays. Feeder circuits can be installed with a common neutral to serve two or three sets of 3-wire feeders, or two sets of four- or five-wire feeders. Feeders installed in a metal raceway and that use a common neutral must have all the conductors involved inclosed in the same raceway. A feeder that supplies branch circuits having grounded conductors must provide a grounding means to which the branch circuit grounding conductors are connected.

**Exercises (242):**

1. What is a branch circuit?

2. Where is a feeder circuit found in a building that has only one panelboard?

3. Most panelboards furnished power by feeder circuits are used for what purpose?

4. What is the purpose of subfeeders?

5. What are three advantages of using feeder circuits in a building instead of just having branch circuits?

6. What is the main objective when installing electrical circuits?

7. Which method is commonly used for circuit installation when there is little chance of damage or moisture contamination?

8. Besides the method used in the preceding exercise, list three other general methods of installing electrical circuits.

9. What are the special installation requirements when a common neutral is used with two or more feeder circuits to be installed in a metal raceway?

# Planning and Laying Out Work

THE FIRST THING you will need before attempting to install any circuit is something that tells you exactly what size the circuit is and where the circuit is to be located. This information usually is contained in a blueprint or drawing of some kind. Therefore, it is necessary that you are able to read and interpret drawings and blueprints.

## 5-1. Blueprint Reading

It has been said that a picture is worth a thousand words. Every day you can see that this is true by just observing your surroundings. People have used pictures to convey their thoughts for centuries. It would be difficult for an engineer or architect to describe the exact length, width, or height of a building or what the finished product will look like without a drawing of some type. A word description of a building would be very long and hard to read. Like other workers in the building trades, you need blueprints and drawings to tell you where a circuit is to be located, what size it will be, and to provide other details about the electrical installation.

**243. Define the term "blueprint," identify the parts of a blueprint or drawing, and match the symbols used in electrical drawings with the correct label or name.**

**Parts of a Blueprint.** Blueprints are a set of instructions on how to construct a building or some other structure. They show certain information that could not be given by words alone. The term "blueprint" originally came from a printing process that used blue paper with white lines and symbols. This process has since been reversed, and now you get white paper with blue, black, or brown lines, but the term has carried over and is in common usage today. They are also called plans or drawings. These blueprints or plans show by means of lines and symbols the shape and size (by reduction to scale) of a structure, the materials required, and the location of fixtures and outlets.

The set of plans drawn up by an architect or engineer, containing all of the information and dimensions necessary to carry a job through to completion, are called working drawings. Reproductions of these drawings are called a set of blueprints. In order for you to be able to read these drawings, you must know what the lines, scales, and symbols mean and how to apply them.

*Plot plan.* The plot plan is the starting point for any building that is to be constructed. It shows where the building is to be placed on the plot of land or property and shows the shape and dimensions of the plot. When the plot plan is bounded by streets or drives, such information is also shown.

The plot plan aids the electricians by showing the point where the service drop from the pole is to be connected or what route the cable will need to be run for an underground service.

*Exterior elevations.* The exterior elevation drawings show views of the finished exterior sides of the buildings. They show exterior trim, finish, window and door openings, roofing, and brickwork. Finished gradelines and floorlines are also shown. You may find this information helpful in locating outside lights and receptacle outlets.

*Interior elevations.* The interior elevations show views of inside wall space that contain counters, sinks, cupboards, and other special features. These drawings can be of great help in determining where to place receptacle outlets and switches in kitchens and bathrooms. The material that is to be used for walls also affects the depth to which the boxes will be mounted.

*Sectional or detail drawings.* These drawings are often added to others to show a specific detail. They may be a cross-sectional view of the building supports or foundation. They could be used to show story height and ceiling height. They may be used to show what floors are made of, whether they have wooden joists or some other type of construction. Any of these things might influence the method of doing electrical work and the kind of material that is to be used.

*Floor plan.* This drawing is the one most used by an electrician. It shows exactly what the name implies, a plan of the floor. The drawing includes the layout of all interior and exterior walls, including windows and doors. It also shows all the wiring requirements. A typical floor plan is shown in figure 5-1.

All of the drawings mentioned thus far are proportional reductions of the final structure. The amount of reduction depends on the size drawing desired. Dimensions in feet are reduced to parts of an inch. For example, 1 foot may be reduced to 1/4 or 1/8 of an inch. The reduction is called the scale on the drawing. If the scale of a drawing is 1/4" = 1', a 1-inch line would represent 4 feet on the actual structure.

**Symbols.** The location of outlets, switches, fixtures, etc, is shown on a floor plan by means of pictures that represent the actual device. These pictures are called symbols and are standardized, for ease of understanding, by those who make the drawings and those who read the drawings. A set of standard symbols, put out by the American National Standards Institute (ANSI), is used for electrical blueprints and drawings. A few of the more common symbols you will see and use are shown in figure 5-2. You should learn these symbols and be able to associate the symbol with the wiring device it represents.

**Legends and Specifications.** Legends used with floor plans or other drawings are a clarification of the symbols

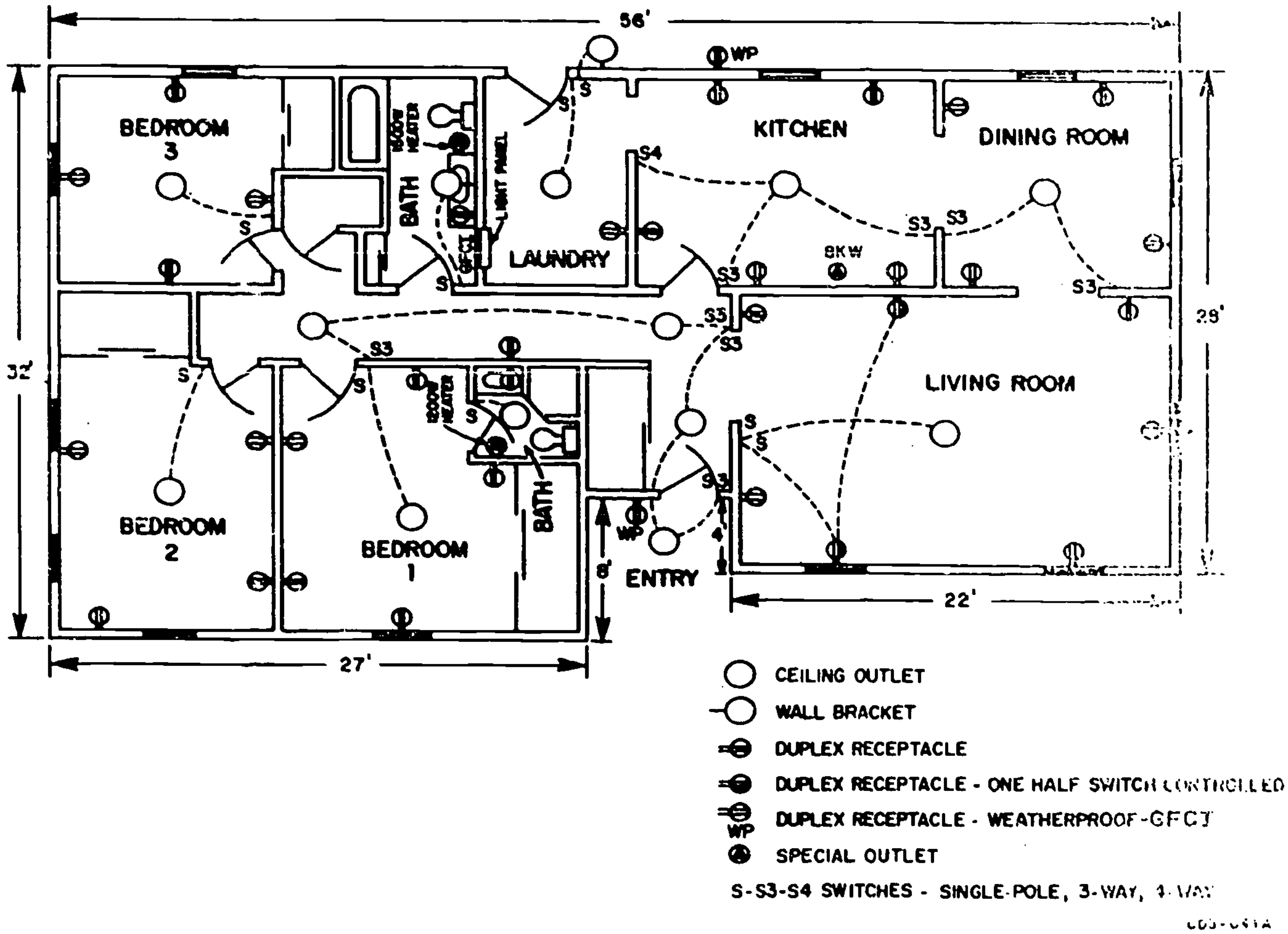



Figure 5–1. Typical floor plan.

used on that particular drawing. (See fig. 5-1, lower right-hand corner.) The legend helps other workers, who may not be familiar with electrical symbols, determine where outlets and switches will be installed. It can also be of help to the electrician if standard symbols are not used.

Specifications are also a vital part of a set of drawings. They are used to clarify information shown on the drawings. They are written instructions that pertain to the materials that will be used to complete the job. Some of the things included in the specifications may be types and kinds of materials, dimensions, colors, quality, finishes, and other details. "Specs" also give a running account of the installation of the electrical equipment on a job. This will enable the electrician to go ahead with the job even though a similar job has never been done.

**Exercises (243):**

1. What is a blueprint?

2. List five of the drawings usually included in a set of blueprints.

3. What is included in a plot plan that would be helpful to an electrician?

4. Describe an exterior elevation.

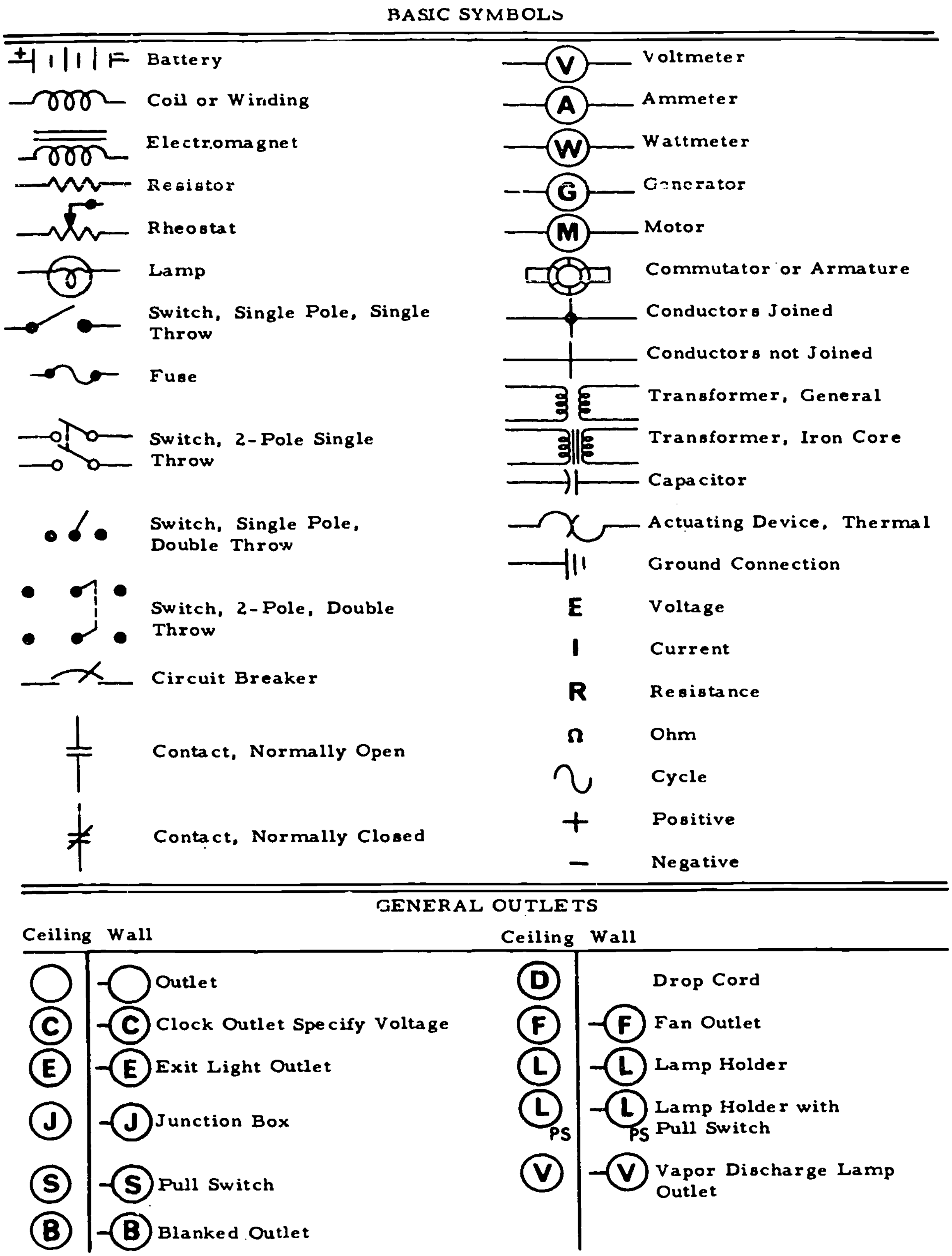



Figure 5–2. Symbols.

## CONVENIENCE OUTLETS

| | | | |
| --- | --- | --- | --- |
| | Duplex Convenience Outlet | 1,3 | Convenience Outlet Other Than Duplex 1=Single, 3=Triple, Etc. |
| WP | Weatherproof Convenience Outlet | R | Range Outlet |
| S | Switch and Convenience Outlet | R | Radio and Convenience Outlet |
| | Special Purpose Outlet, Describe in Specifications | | Floor Outlet |

## SWITCH OUTLETS

| | | | |
| --- | --- | --- | --- |
| S | Single Pole Switch | S 4 | Four-Way Switch |
| S 3 | Three-Way Switch | S E | Electrolier Switch |
| S D | Automatic Door Switch | S P | Pilot Lamp and Switch |
| S K | Key-Operated Switch | S WCB | Weatherproof Circuit Breaker |
| S CB | Circuit Breaker | S RC | Remote Control Switch |
| S MC | Momentary Contact Switch | S F | Fused Switch |
| S WP | Weatherproof Switch | S WF | Weatherproof Fused Switch |
| S 2 | Double Pole Switch | | |

## PANELS AND CIRCUITS

| | | | |
| --- | --- | --- | --- |
| | Lighting Panel | | Power Panel |
| | Feeders - Use Heavy Lines and Show by Number Same as in Feeder Schedule | | Branch Circuit Concealed in Ceiling or Wall |
| | Branch Circuit Concealed in Floor | | Branch Circuit Exposed |
| | Home Run to Panel Board Number of Circuits Indicated by Number of Arrows | | |
| | Any Circuit Without Further Designation Indicates a Two-Wire Circuit. A greater Number of Wires is Indicated Thus | | (3 Wires) or (4 Wires) |

## MISCELLANEOUS SYMBOLS

| | | | | | |
| --- | --- | --- | --- | --- | --- |
| | Pushbutton | | Buzzer | | Bell |
| D | Electric Door Opener | F | Fire Alarm Station | F | Fire Alarm Bell |
| | Controller | H | Horn | N | Nurse's Signal Plug |
| | Isolating Switch | | Radio Outlet | T | Bell Ringing Transformer |
| | Annunciator | | | | |

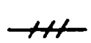
Figure 5-2. Symbols (contd).

5. Interior elevations contain what type of information that would be helpful when installing outlets and switches?

6. Which of the blueprint drawings shows the layout of all the walls and is most helpful to the electrician?

7. If the scale of a drawing is 1/8" = 1', what distance would a line 2 inches long represent?

8. Using figure 5-3, match the symbols in column 2 with the correct label or name in column 1 by placing a number in the blank provided.

| COLUMN 1 | | COLUMN 2 |
|---|---|---|
| ____ a. |  | 1. SINGLE POLE SWITCH |
| ____ b. |  | 2. CEILING OUTLET |
| ____ c. | $S_4$ | 3. POWER PANEL |
| ____ d. |  | 4. RANGE OUTLET |
| ____ e. |  | 5. FOUR—WAY SWITCH |
| ____ f. | ------ | 6. LIGHTING PANEL |
| ____ g. |  | 7. SPECIAL PURPOSE OUTLET |
| ____ h. | S | 8. JUNCTION BOX IN WALL |
| ____ i. | ○ | 9. 3—WIRE BRANCH CIRCUIT CONCEALED |
| ____ j. | → | 10. HOME RUN TO PANEL |
| ____ k. |  | 11. THREE—WAY SWITCH |
| ____ l. | $S_3$ | 12. BRANCH CIRCUIT EXPOSED |
| ____ m. |  | 13. DUPLEX CONVENIENCE OUTLET |

CEQ-025

Figure 5–3. Symbol identification (objective 243, exercise 8).

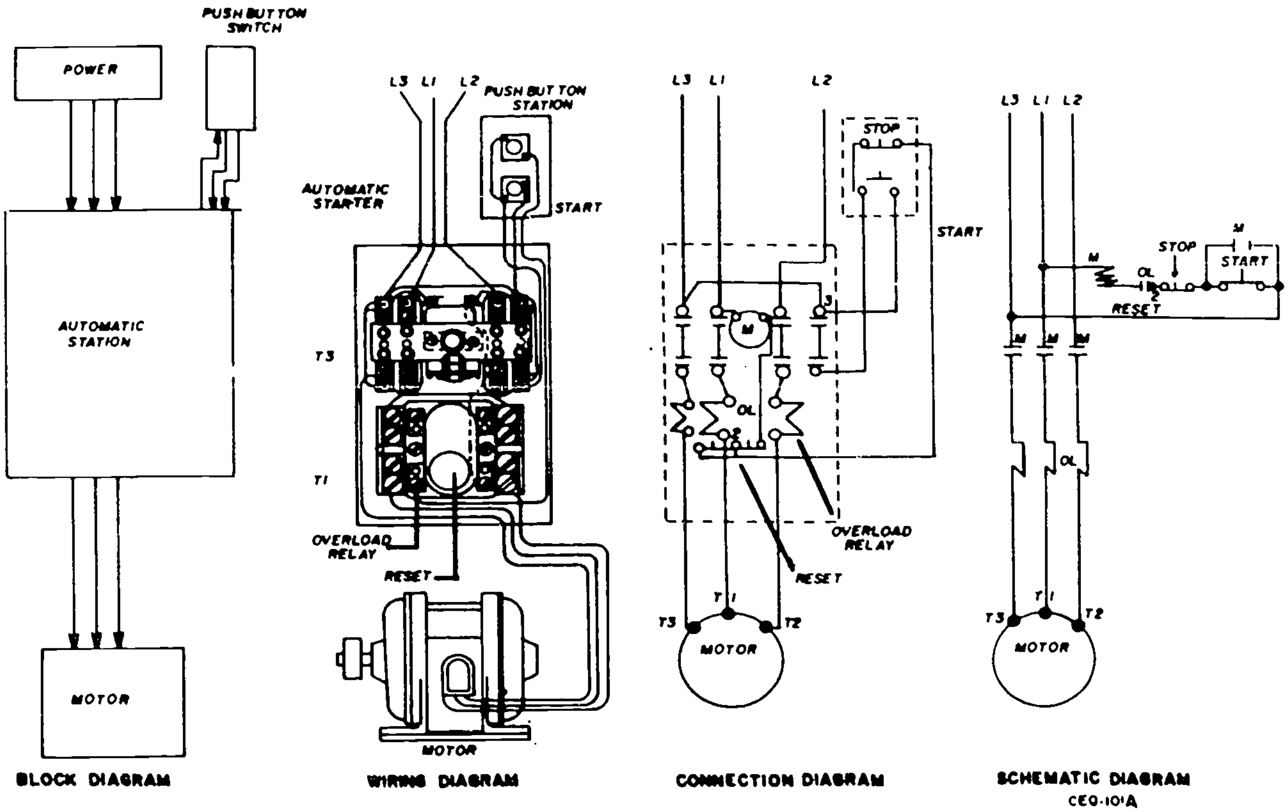



Figure 5-4. Electrical diagrams.

**244. Identify characteristics of electrical diagrams.**

In addition to the drawings in a set of blueprints, you will be working with drawings called electrical diagrams.

**Electrical Diagrams.** A diagram is defined as a line drawing that shows arrangement or relationship of parts. Electrical diagrams are usually used to show how parts of a piece of equipment or several pieces of equipment are wired together. There are basically four types of electrical diagrams. These diagrams are similar to each other and their names are sometimes used interchangeably, but they do have differences.

*Block diagram.* A block diagram is a simple drawing showing the relationship of major parts of a system. Figure 5-4, far left, shows a block diagram of a motor control system. You can easily see why it is called a block diagram. The parts or components in any block diagram will be shown just as they appear in this drawing, as blocks. They are then connected by a line or lines that show the relationship of the parts. Block diagrams are often used to explain power- distribution systems. Figure 4-14, in Chapter 4, is a good example of a distribution system block diagram. The internal connections of the components are not shown in these drawings. The blocks are simply labeled to show what each represents. These drawings would be of little help for troubleshooting.

*Wiring diagram.* The wiring diagram, which is like a picture drawing, shows the wiring between components and the relative position of the components. The second diagram from the left in figure 5-4 shows a wiring diagram of the same motor control system shown by the block diagram. You can see that instead of blocks used to show components, a picture of the component is used. You can also see that the lines used to show the wiring are marked numerically or alphanumerically. Lines L1, L2, and L3 are incoming power leads and the diagram shows which terminals they are connected to in the starter. Wiring diagrams are often used along with a list of repair parts and can be used to do some troubleshooting.

*Connection diagram.* The third diagram shown in figure 5-4 is a connection diagram. It makes use of diagram symbols instead of pictures to show components. It also shows all the internal and external circuit connections, and these can be read and traced more easily than on the wiring diagram. In the connection diagram, the components are still shown in their relative positions. This diagram can be used to help you connect all the wiring and trace any part of the circuit, which makes it a very valuable troubleshooting tool. It is often found inside the cover of a piece of equipment.

*Schematic diagram.* The schematic diagram is a drawing that shows the electrical plan of operation of a piece of equipment or component. The relative position of parts is

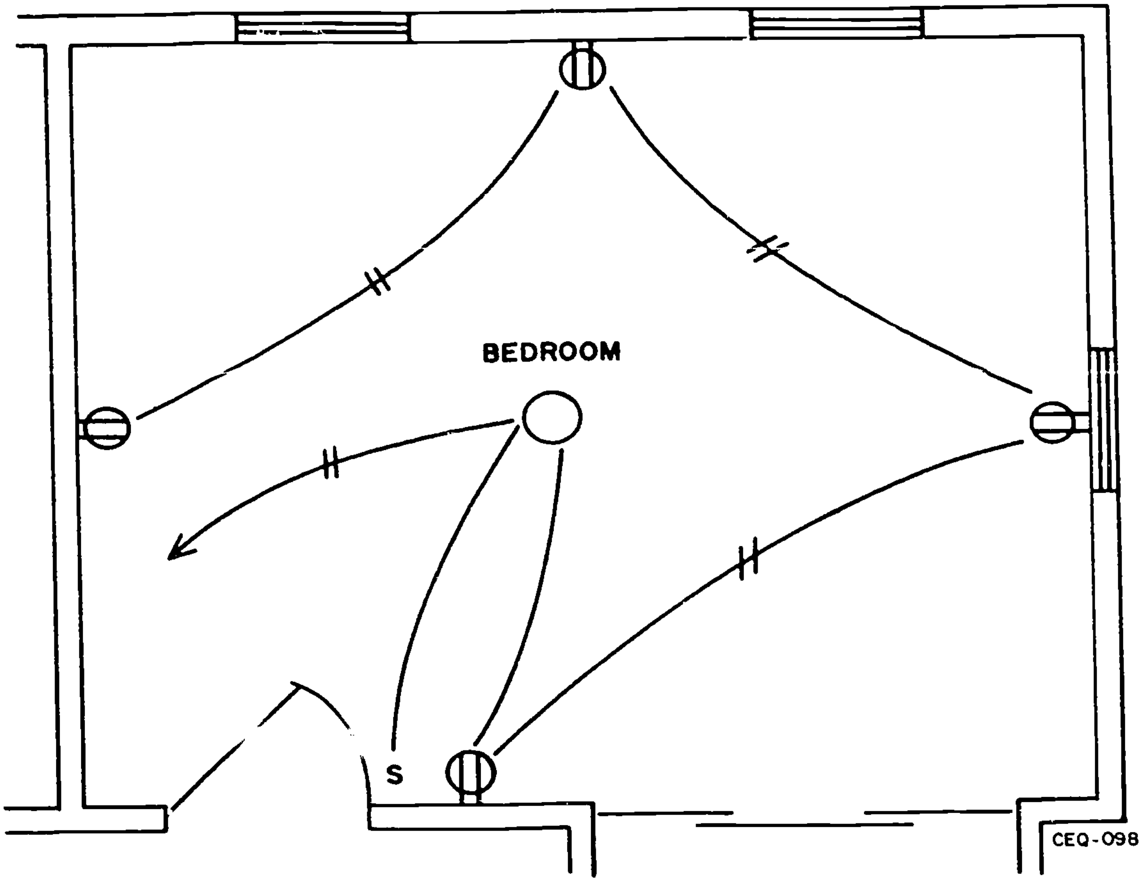



Figure 5–5. Bedroom floor plan.

not shown in this type of diagram. The schematic diagram, like the connection diagram, makes use of symbols instead of pictures. The schematic shown in figure 5-4 is of the same motor control system shown in the other three diagrams. It is laid out so that the components are in line to make it easy to trace the operation. Notice the use of heavy and light lines in the drawing. In this case, the heavy lines show the main power circuit and the light lines show the control circuit. The schematic is sometimes called an elementary or one-line diagram and is very useful in troubleshooting or tracing the plan of operation.

**Exercises (244):**

Identify each correct statement by placing a T in the blank provided and an F for those that are false. Correct false statements.

_____ 1. There are basically three types of electrical diagrams: the one-line, block, and schematic diagrams.

_____ 2. The three diagrams that show physical relationship of parts or components are the block, wiring, and connection diagrams.

_____ 3. The block diagram is often used to show or explain power distribution systems.

_____ 4. Wiring diagrams often use pictures to show components and are often accompanied by a parts list.

_____ 5. The connection diagram is the only diagram that shows relative position of the components, as well as all the circuit connections.

_____ 6. The diagram that makes it easy to trace the electrical operation is called the wiring diagram.

where connections will be required, and how the connections are color coded. It will be similar to the electrical diagrams discussed previously and will show as much detail as the electrician wants to use. Most of the time you will need to make a working sketch to help you in the installation of circuits. Here is an example of how it is done. Figure 5-5 is part of the floor plan of a house (in this case a bedroom). The symbols show that there is a home run (incoming power) to a lighting outlet in the ceiling, near the center of the room. It also shows that this lighting outlet is controlled by a switch just inside the door. The remaining symbols show a duplex receptacle outlet on each wall; the first one being fed from the ceiling outlet. The other outlets are then fed, in turn, off the first one. All circuit runs are shown as two conductors concealed in the wall or ceiling.

Now what we know that the floor plan shows, let's see what it does not show, and then take a look at a working sketch to see how it helps. First of all, the floor plan does not show the circuit connections or electrical opera tion, as a schematic diagram would. There is nothing in the drawing that shows where splices might have to be made and, assuming the circuit is to be wired with cable, there is no way to show color coding. Figure 5-6 is a working sketch of the floor plan shown in figure 5-5. Several things have been added to this sketch that you would not need to include in a sketch of your own. These are the dotted lines that represent boxes and the heavy lines, and symbols taken from the floor plan. They have been included here simply to clear up a few points. The required equipment grounds have been left out to avoid confusion.

Your first step, if you were drawing the sketch, would be to draw the symbols that represent all the devices that are to be in the circuit. They should be drawn in sequence, starting with the outlet that is connected to the home run. Notice that the ceiling outlet in figure 5-5 has the home run, a switch, and a receptacle outlet connected to it. It should be drawn so that it is nearest the power source in your drawing. The outlet will also serve as a junction box where splices in the wiring will be made. After the symbols are drawn, you should add the terminal connections that are required at each outlet. The sketch in figure 5-6 shows these terminals as S (silver) and G (gold) at the ceiling light and the receptacle outlets. The two terminals at the switch are not marked. The final step is to connect the wires and color code them. Start these connections at the power source. The floor plan shows two wires in the home run. One will be the hot (black) wire; the other, the neutral (white) wire. At the ceiling outlet, the hot wire will need to be spliced to provide power to the switch and to the gold terminals of all the receptacle outlets. The ceiling light receives its power from the switch. The switch is put in a loop of hot wire that runs from the hot wire splice just mentioned to the switch, and from there back to the gold terminal on the light. As you can see from the sketch, this hot wire loop (switch leg) has both a white and a black wire. The white wire goes from the splice to the switch. This is the only time that a hot wire can be white. This exception is allowed by the NEC when wiring with nonmetallic sheathed cable, because you are limited to the wire colors available in the cable. The neutral wire from the power source will also have to be spliced at the ceiling outlet to provide a neutral for both the light and the receptacles. The neutral is connected to the silver terminal of the light fixture and of all the receptacles.

**245. Given a floor plan of a room with an electrical circuit shown, translate the information from the plan by drawing a working sketch to show how the circuit should be connected.**

As you have learned thus far, the information provided in the floor plan of a blueprint is limited to what circuits are to be installed, the devices that will be in the circuits, and where they are located. Circuit diagrams that show the actual wiring and the needed connections for the circuits are not provided with floor plans. Therefore, before you can start installing the circuits and components, you must be able to translate the information in the floor plan to a working sketch.

*Working sketch*. A working sketch is a drawing or sketch made by the electrician before starting the required work. It is drawn to help determine what size boxes will be needed,

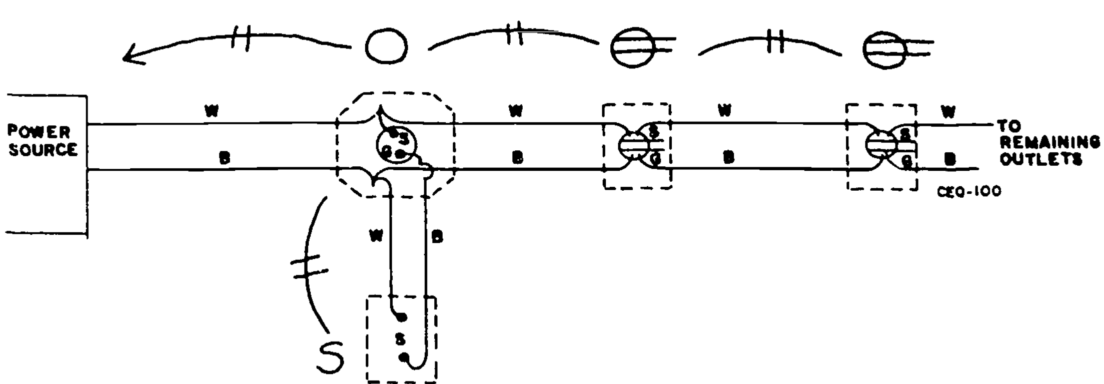



Figure 5–6. Working sketch.

**Exercises (245):**

1. Draw a working sketch of the circuit shown in figure 5-7. Show all necessary splices, terminal connections, and conductor identification.

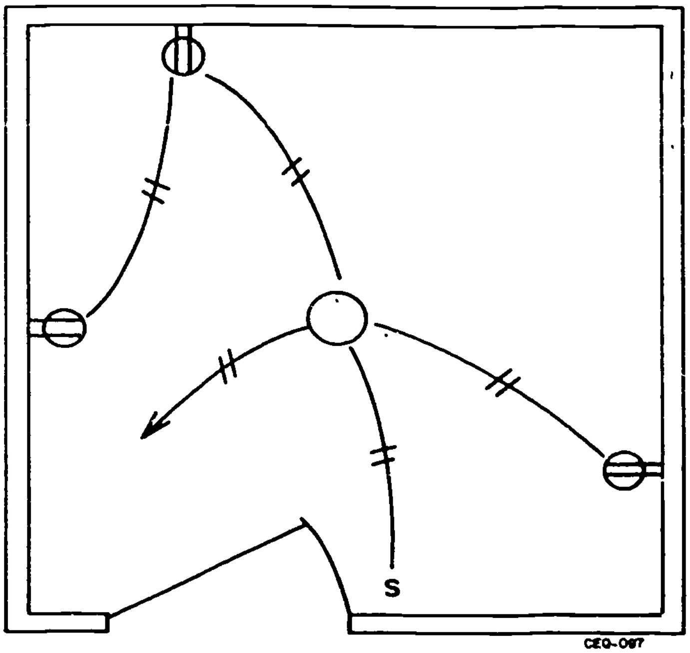



Figure 5–7. Floor plan (objective 245, exercise 1).

## 5-2 Calculating Power Requirements

Calculating a wiring system from beginning to end requires a broad knowledge of principles, tools, and techniques. Your main concern when calculating a wiring installation is safety. Electrical safety refers to preventing fire and electrical shock. Your key to success in calculating an electrical system is using a proven standard of the construction industry. The standard for electrical construction is the *National Electrical Code*, (NEC) sponsored by the National Fire Protection Association.

**246. Given a floor plan with an electrical drawing, calculate the power requirement of the circuits on the plan.**

**Calculating Residential Wiring.** To aid you in your study, foldouts 1 and 2 are provided at the end of the volume. Foldout 1 is an electrical floor plan of a single dwelling; foldout 2 is an electrical floor plan of an industrial location. Refer to the foldouts whenever necessary.

We begin our calculating lesson using foldout 1, single dwelling. The loads we will calculate are for general lighting circuits, special-purpose circuits, and the power requirements for the service equipment.

*General Lighting Load.* The general lighting load is computed on the watts per square foot basis. NEC 220–2(b), "In determining load on the watts per square foot basis, outside dimensions of the building shall be used, not including open porches, garages, nor unfinished and unused spaces unless adaptable for future use." The term "unless adaptable for future use" means basement and attic areas that could be converted to bedrooms or recreation rooms at a later time.

To find the square footage on foldout 1, multiply the length times the width, or 57 feet, the length of the back wall, times 28 feet, the width of the dining room and living room wall. The total is 1596 square feet. This is not our total figure. Look at foldout 1 closely. The measurement we made was a square that extended across the back wall and down the right hand wall. We cut across the open porch, through the closet and bedroom 1, and through bedroom 2. We need the remainder of the bedroom measurements and one additional measurement to complete the square foot calculation.

The left-hand wall, or outside wall of bedrooms 2 and 3, is 32 feet long. This is 4 feet longer than the right-hand wall of 28 feet. To figure this area, multiply 4 feet times the 27 feet along the front of the dwelling to the porch. The total is 108 square feet. We add this figure to our original figure of 1596 square feet, equaling 1704 feet overall. We are almost finished, only one more area to go.

Now we will calculate and subtract the open porch. Our first calculation used 4 feet of this area from the doorway out to the front edge of the living room wall. To find the width of the porch, add the two front walls, 27 feet plus 22 feet, equaling 49 feet. Subtracting 49 feet from the rear wall of 57 feet leaves 8 feet, or the width of the porch. Multiply the 8 foot width by 4 feet for 32 square feet of porch area. If we subtract the 32 square feet from our 1704 square feet overall, we find the total square footage for lighting on foldout 1 at 1672 square feet.

NEC table 220-2(b), see figure 5-8, general lighting loads by occupanices, shows the unit load per square foot for dwellings is 3 watts. Foldout 1 has 1672 square feet. Multiply 1672 by 3 watts, this equals 5,016 watts, our general lighting load.

NEC 220-3(d) "Watts per-square-foot load shall be apportioned evenly among branch circuits." To find the number of lighting branch circuits, divide 5,016 watts by 115 volts. This figures out at 43.6 amps. We will require three lighting circuits on foldout 1, 15 amps each, for an evenly distributed load.

*Minimum requirements for special purpose outlets.* We will now figure the minimum requirements for special outlets for a single dwelling.

*a.* NEC 220–3(c), requires a 20-amp, 1500 watt dedicated outlet in the laundry. You can see this outlet on foldout 1.

*b.* NEC 220–3(b)(2), requires two or more 20 amp small appliance branch circuits in the kitchen and dining room. You can see these outlets marked A and B on foldout 1. Each circuit is required to have a 1500 watt capacity.

*c.* NEC 210–23, allows branch circuits to be installed for specific loads. On foldout 1 we have five branch circuits installed. A heater in each bath, a dryer in the laundry

**Table 220-2(b). General Lighting Loads by Occupancies**

| Type of Occupancy | Unit Load per Sq. Ft. (Watts) |
|---|---|
| Armories and Auditoriums | 1 |
| Banks | 3½** |
| Barber Shops and Beauty Parlors | 3 |
| Churches | 1 |
| Clubs | 2 |
| Court Rooms | 2 |
| *Dwelling Units | 3 |
| Garages — Commercial (storage) | ½ |
| Hospitals | 2 |
| *Hotels and Motels, including apartment houses without provisions for cooking by tenants | 2 |
| Industrial Commercial (Loft) Buildings | 2 |
| Lodge Rooms | 1½ |
| Office Buildings | 3½** |
| Restaurants | 2 |
| Schools | 3 |
| Stores | 3 |
| Warehouses (storage) | ¼ |
| In any of the above occupancies except one-family dwellings and individual dwelling units of multifamily dwellings: | |
| Assembly Halls and Auditoriums | 1 |
| Halls, Corridors, Closets | ½ |
| Storage Spaces | ¼ |

For SI units: one square foot = 0.093 square meter.

* All receptacle outlets of 20-ampere or less rating in one-family and multifamily dwellings and in guest rooms of hotels and motels [except those connected to the receptacle circuits specified in Section 220-3(b)] shall be considered as outlets for general illumination, and no additional load calculations shall be required for such outlets.

** In addition a unit load of 1 watt per square foot shall be included for general purpose receptacle outlets when the actual number of general purpose receptacle outlets is unknown.

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Figure 5–8. NEC Table 220–2(b).

room, the air conditioner, and a 1/4-horse-power fan motor in the laundry room.

*Service Load.* We are now ready to calculate the total service load of foldout 1.

*a*. Air conditioning at 12,500 watts.
*b*. Lighting load at 5,016 watts.
*c*. Small appliance load at 3,000 watts.
*d*. Laundry load at 1,500 watts.
*e*. Dryer load at 5,000 watts.

We did not calculate the 1/4-horse-power fan motor in the laundry room. (NOTE: 10, on foldout 1, reminds us the motor in the laundry room was figured into the 12.5 kW air-conditioning unit as a total package unit. The bathroom heaters were not calculated, because NEC 220–30(5) requires air- conditioning or heating loads, whichever is largest, be used in calculating, but do not use both. The reason for this is heating and cooling are not operated at the same time.)

Our final calculations for foldout 1, were computed as follows:

*a*. The air-conditioning load was figured at 100 percent of the data plate rating of 12,500 watts.

*b*. The lighting load, small appliance and laundry load, and the dryer were added together. This total, 14,516 watts, was calculated at 100 percent of the first 10,000 watts and 40 percent of the remaining wattage over 10,000 watts. This was 40 percent of 4,516 watts or 1,806 watts. We use this 40 percent factor, assuming very few families will consume over 10 kW of power, 100 percent of the time. In other words, we estimate every single electrical circuit will not be used at the same time.

The total calculated load is the air conditioner at 12,500 watts, plus the first 10,000 watts of the other load, plus the remainder of the other load (4,516 watts) at 40 percent or 1,806 watts. The total is 24,306 watts for foldout 1.

Our service entrance was calculated using a 3-wire, 115/230 volt underground service. We convert 24,306 watts, to amps, by dividing by 230 volts. This equals 105.6 amps for our service. We used table 310–16, NEC, see figure 5-9, and found #2 THW copper conductors are rated at 115 amps in a raceway. Our main fuses, or circuit breakers were selected at 110 amps by using the following standard ampere ratings for fuses and inverse time circuit breakers: 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000.



**Table 310-16. Allowable Ampacities of Insulated Conductors Rated 0-2000 Volts, 60° to 90°C**

**Not More Than Three Conductors in Raceway or Cable or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)**

| Size | Temperature Rating of Conductor, See Table 310-13 | | | | | | | | Size |
|---|---|---|---|---|---|---|---|---|---|
| | 60°C (140°F) | 75°C (167°F) | 85°C (185°F) | 90°C (194°F) | 60°C (140°F) | 75°C (167°F) | 85°C (185°F) | 90°C (194°F) | |
| AWG MCM | TYPES †RUW, †T, †TW, †UF | TYPES †FEPW, †RH, †RHW, †RUH, †THW, †THWN, †XHHW, †USE, †ZW | TYPES V, MI | TYPES TA, TBS, SA, AVB, SIS, †FEP, †FEPB, †RHH, †THHN, †XHHW* | TYPES †RUW, †T, †TW, †UF | TYPES †RH, †RHW, †RUH, †THW, †THWN, †XHHW, †USE | TYPES V, MI | TYPES TA, TBS, SA, AVB, SIS, †RHH, †THHN, †XHHW* | AWG MCM |
| | COPPER | | | | ALUMINUM OR COPPER-CLAD ALUMINUM | | | | |
| 18 | .... | .... | .... | 14 | .... | .... | .... | .... | .... |
| 16 | .... | .... | 18 | 18 | .... | .... | .... | .... | .... |
| 14 | 20† | 20† | 25 | 25† | .... | .... | .... | .... | .... |
| 12 | 25† | 25† | 30 | 30† | 20† | 20† | 25 | 25† | 12 |
| 10 | 30† | 35† | 40 | 40† | 25† | 30† | 30 | 35† | 10 |
| 8 | 40 | 50 | 55 | 55 | 30 | 40 | 40 | 45 | 8 |
| 6 | 55 | 65 | 70 | 75 | 40 | 50 | 55 | 60 | 6 |
| 4 | 70 | 85 | 95 | 95 | 55 | 65 | 75 | 75 | 4 |
| 3 | 85 | 100 | 110 | 110 | 65 | 75 | 8 | 85 | 3 |
| 2 | 95 | 115 | 125 | 130 | 75 | 90 | 100 | 100 | 2 |
| 1 | 110 | 130 | 145 | 150 | 85 | 100 | 110 | 115 | 1 |
| 0 | 125 | 150 | 165 | 170 | 100 | 120 | 130 | 135 | 0 |
| 00 | 145 | 175 | 190 | 195 | 115 | 135 | 145 | 150 | 00 |
| 000 | 165 | 200 | 215 | 225 | 130 | 155 | 170 | 175 | 000 |
| 0000 | 195 | 230 | 250 | 260 | 150 | 180 | 195 | 205 | 0000 |
| 250 | 215 | 255 | 275 | 290 | 170 | 205 | 220 | 230 | 250 |
| 300 | 240 | 285 | 310 | 320 | 190 | 230 | 250 | 255 | 300 |
| 350 | 260 | 310 | 340 | 350 | 210 | 250 | 270 | 280 | 350 |
| 400 | 280 | 335 | 365 | 380 | 225 | 270 | 295 | 305 | 400 |
| 500 | 320 | 380 | 415 | 430 | 260 | 310 | 335 | 350 | 500 |
| 600 | 355 | 420 | 460 | 475 | 285 | 340 | 370 | 385 | 600 |
| 700 | 385 | 460 | 500 | 520 | 310 | 375 | 405 | 420 | 700 |
| 750 | 400 | 475 | 515 | 535 | 320 | 385 | 420 | 435 | 750 |
| 800 | 410 | 490 | 535 | 555 | 330 | 395 | 430 | 450 | 800 |
| 900 | 435 | 520 | 565 | 585 | 355 | 425 | 465 | 480 | 900 |
| 1000 | 455 | 545 | 590 | 615 | 375 | 445 | 485 | 500 | 1000 |
| 1250 | 495 | 590 | 640 | 665 | 405 | 485 | 525 | 545 | 1250 |
| 1500 | 520 | 625 | 680 | 705 | 435 | 520 | 565 | 585 | 1500 |
| 1750 | 545 | 650 | 705 | 735 | 455 | 545 | 595 | 615 | 1750 |
| 2000 | 560 | 665 | 725 | 750 | 470 | 560 | 610 | 630 | 2000 |

**CORRECTION FACTORS**

| Ambient Temp. °C | For ambient temperatures over 30°C, multiply the ampacities shown above by the appropriate correction factor to determine the maximum allowable load current. | | | | | | | | Ambient Temp. °F |
|---|---|---|---|---|---|---|---|---|---|
| 31-40 | .82 | .88 | .90 | .91 | .82 | .88 | .90 | .91 | 86-104 |
| 41-45 | .71 | .82 | .85 | .87 | .71 | .82 | .85 | .87 | 105-113 |
| 46-50 | .58 | .75 | .80 | .82 | .58 | .75 | .80 | .82 | 114-122 |
| 51-60 | .... | .58 | .67 | .71 | .... | .58 | .67 | .71 | 123-141 |
| 61-70 | .... | .35 | .52 | .58 | .... | .35 | .52 | .58 | 142-158 |
| 71-80 | .... | .... | .30 | .41 | .... | .... | .30 | .41 | 159-176 |

† The load current rating and the overcurrent protection for conductor types marked with an obelisk (†) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum.

* For dry locations only. See 75°C column for wet locations.

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Figure 5–9. NEC Table 310–16.

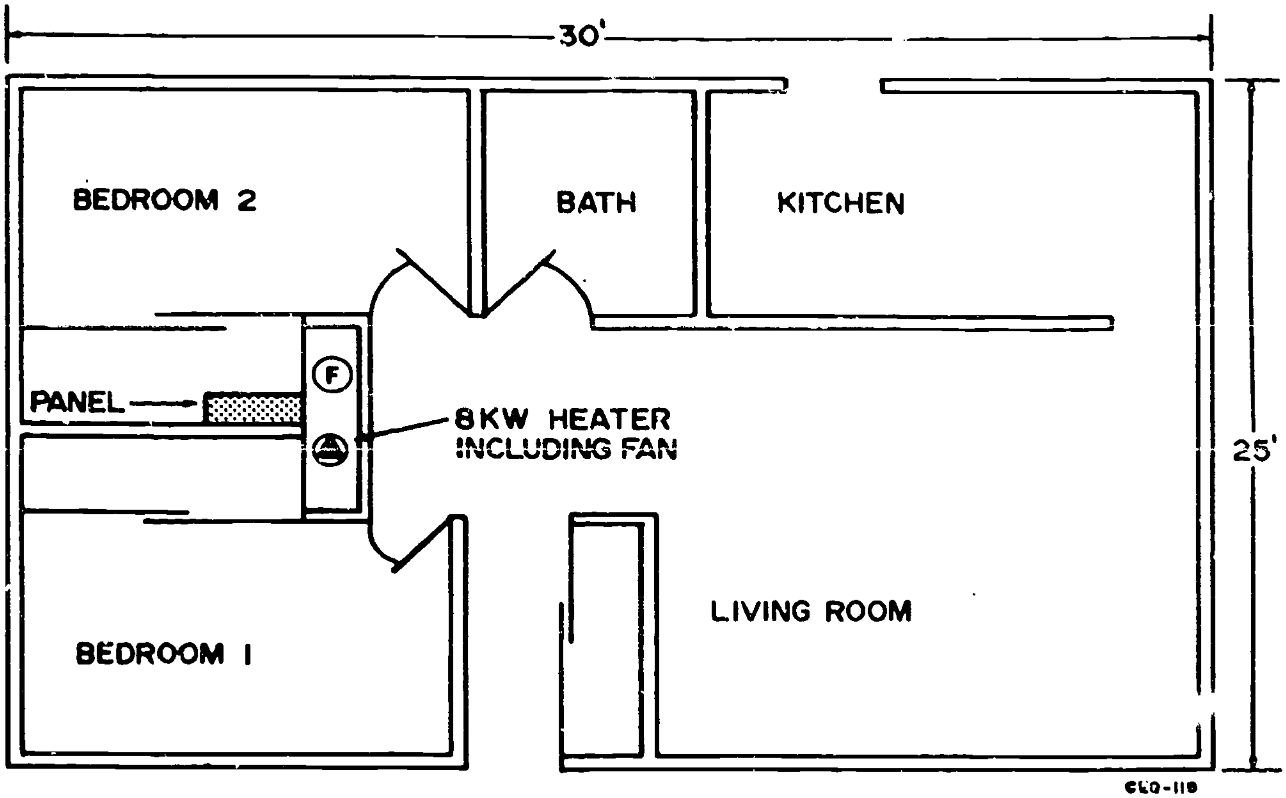


Figure 5–10. Floor plan (objective 246, exercise 1-7).

**Exercises (246):**

Using figure 5-10, solve the following problems based on a 3-wire, 115/230 volt power source, and copper conductors with TW insulation.

1. Total square footage of the building?

2. Total wattage for lighting?

3. Number of lighting circuits required at 1500 watts each?

4. List the recommended and special circuits required:

5. Compute the total load of figure 5-10.

6. Size of service entrance conductors required?

7. Size of service entrance overcurrent protection required?

**247. Given specifications for an industrial lighting installation, calculate the power requirements and determine the size of conductors and protective devices required.**

**Industrial Wiring.** Industrial wiring is different from dwelling wiring in several ways.

- Most industrial wiring is exposed in conduit.
- Industrial power is usually 3- phase, 3- or 4-wire systems.
- Industrial wiring normally provides power to large inductive loads like motors, ballasts, and transformers.
- A separate transformer is used to step down power for low voltage lighting and appliances.
- The lighting load is calculated, primarily by the type of fixtures used.

We will begin our calculations on foldout 2 with the lighting load for the building, starting in the offices. NEC 210–22(b) requires the load on a ballast operated light

fixture be calculated according to the ampere rating of the ballast. The note on foldout 2 tells us the fluorescent fixtures in the offices have ballasts rated at 2.6 amperes each. There are 15 fixtures multiplied by 2.6 amps, giving us a total of 39 amps. Converted to watts, (IXE) (39A × 120V) = 4680 watts.

Figure 5-8, NEC table 220-2(b) at the bottom of the page requires adding 1 watt per square foot for general purpose outlets in the offices when the actual number is unknown. The offices measure 12 × 40 feet or 480 additional watts. Our office lighting load is now 4680 watts + 480 watts totaling 5,160 watts.

We are required to increase this load, or any branch circuit load that is continuous (load is expected to continue for 3 hours or more), by 25 percent. This would be 6,450 watts for our calculated office load.

The branch circuit protection cannot be loaded to more than 80 percent of it's rating under the limitations imposed by NEC 210-22(c) since the load continues for a long period of time. A 20-amp circuit normally can supply 2400 watts of power (20A × 120V) but, because of the 80 percent limitation, the circuit will only carry 1920 watts of power (80 percent of 2400 watts). We would need a minimum of four branch circuits in panel B-2, using No. 12 AWG copper conductors, and must protect each circuit with a 20 amp circuit breaker. (NOTE: AFM 85-24 limits No. 12 AWG conductors as the smallest size conductor to be used for general wiring. See figure 5-9, NEC table 310-16, for allowable ampacities of insulated conductors No. 12 and larger.)

The machine shop, in the center of foldout 2, has 16 flourescent fixtures. See note 3. Each ballast is rated at 1.7 amps on 277 volts. 16 fixtures × 1.7 amps equals 27.2 amps. Converting to watts (27.2A × 277V) = 7,534 watts. This is a continuous load requiring an additional 25 percent of 7,534 watts or (7534W + 1883W) = 8,417 watts, for our calculated machine shop load.

The branch circuit protection can not be more than 80 percent of its rating. A 20-amp circuit on 277V normally can supply 5540 watts. (80 percent of 554OW = 4432 watts.) We would need a minimum of two branch circuits on panel A-2, using No. 12 AWG copper conductors, and must protect each circuit with a 20-amp circuit breaker.

The hangar area lighting is calculated using NEC 220-2(c)(4), "outlets for heavy duty lampholders are calculated at 600 volt-amperes." This is 600 divided by 277 volts or 2.16 amperes for each light fixture in the hangar. Foldout 2, note 1, lists 16 fixtures in each hangar. 16 × 2.16 amps = 34.56 amps. Converting this to watts equals (34.56 × 277V) or 9,573 watts. A 25-percent increase for a continuous load is 9,573W + 2,393W = 11,966W.

The branch circuit protection at an 80-percent rating equals 80 percent of 5540W (20A at 277V) or 4432W. We need a minimum of three branch circuits in each hangar, on No. 12 AWG copper conductors, and three 20 amp circuit breakers installed in panels A-1 and A-2.

Note 4 on foldout 2 lists the requirements of several rooms all using 150-watt, 120-volt, incandescent fixtures; two in the equipment room, four in the latrine, and four in the break room. We can calculate the 10 fixtures at 10 × 150 watts or 1500 watts total for the three rooms.

Note 5 on foldout 2 lists 4 flourescent fixtures using 1.3 amperes per ballast in the battery room. (4 × 1.3A) = 5.2A. Converted to watts (5.2 × 120V) = 572 watts. Increase this by 25 percent because continuous duty equals 715 watts. A 15A breaker at 120V is rated at 1800 watts, derated to 80 percent it can safely carry 1440 watts. We are still required to use #12 AWG copper conductors from panel C.

There are no notes for the supply room or welding room lighting. We will use the square footage of the rooms and figure 5-8, NEC table 220-2(b). The supply room is 18 × 20 feet; the welding room is 11 X 12 feet. The two rooms equal 492 square feet. Industrial commercial (loft) buildings require 2 watts per sq. ft. 492 × 2 = 984 watts total for the two rooms. It is best to feed the supply room from panel C and the welding room from panel B-3 using 15 amp breakers and No. 12 AWG copper conductors. This would allow the occupants of the rooms to have local access to the circuit breakers.

The lighting load for foldout 2 is figured by adding all the lighting calculations we made for each subpanel.

- Panel C, totaled ....................1,735 watts.
- Panel A-1 totaled ................11,966 watts.
- Panel B-1 totaled .......................0
  (no lighting connected).
- Panel A-2 totaled ................20,383 watts.
- Panel B-2 totaled..................6,450 watts.
- Panel B-3 totaled..................1,464 watts.

Lighting load equals.....................41,998 watts on foldout 2.

**Exercises (247):**

1. Calculate the power requirements in watts for 20 ballast-operated fixtures on 120 volts, 1.7 amps per ballast.

2. Find the total calculated load of a lighting circuit rated continuous duty, drawing 5,300 watts.

3. What size overcurrent device is required on a calculated lighting load of 4767 watts, fed with 277 volts?

4. Calculate the load in watts of 14 heavy duty lampholders fed with 277 volts.

5. What size of TW copper conductors are required for a branch circuit supplying a 3200 watt lighting load fed with 120 volts?

**248. Calculate the ampere requirements and determine the size of conductors, physical protection, and protective devices required for a motor installation.**

**Motor Calculations.** There are numerous rules for calculating motor installations. The rules depend primarily on horse power (hp), amperes (A), voltage (V), phases (0ϕ, the type of rotor used in the motor, and the code letter on the motor data plate. The code letter is used to identify a specific motor's locked-rotor current draw.

Refer to foldout 2, hangar A and the 20 hp motor used to operate the hangar doors. The drawing shows a homerun to panel A-2 with 30ϕ, 480V power supplied. The door motor is operated by an autotransformer providing a lower starting voltage, and results in a reduced inrush current to the motor windings. The motor has a squirrel-cage rotor and no code letter listed.

Figure 5-11, NEC table 430-150 lists the "Full-load current. . ." for 30ϕ, AC, motors. Look down the left-hand column. The hp ratings start at 1/2 and go to 200. Our 20 hp door motor is in the center. Now move across the table to the right, under the 460 volt column of the first section, "Induction Type Squirrel-Cage and Wound-Rotor Amperes." Our 20 hp squirrel-cage motor is rated at 27A. This means the door motor will draw 27A per phase at normal running speed. This is the amperage we use for calculating, and usually name, full-load current (FLC).

Now that we know our motor's FLC we can determine the conductors needed for our motors branch circuit. NEC 430-22 states, "Ampacity of branch-circuit conductors will be not less than 125 percent motor FLC." We figure this by multiplying 27A × 125 percent or 27A X 1.25 equalling 33.75A. See figure 5-9, NEC table 310-16, "Allowable ampacities of Insulated Conductors." The outside columns are wire size. The left half is for copper conductors and the right half is for aluminum- or copper-clad aluminum conductors. We will use copper conductors and TW insulation. The table is broken down into temperature ratings. The 60° C column lists our type of insulation, TW. We are looking for a conductor that will carry 33.75A. The closest is 40A. Move to the left; the size AWG conductor we need is No. 8 copper.

ARTICLE 430—MOTOR CIRCUITS, CONTROLLERS 70-345

**Table 430-150. Full-Load Current***
**Three-Phase Alternating-Current Motors**

| | Induction Type Squirrel-Cage and Wound-Rotor Amperes | | | | | †Synchronous Type Unity Power Factor Amperes | | | |
|---|---|---|---|---|---|---|---|---|---|
| HP | 115V | 230V | 460V | 575V | 2300V | 230V | 460V | 575V | 2300V |
| ½ | 4 | 2 | 1 | .8 | | | | | |
| ¾ | 5.6 | 2.8 | 1.4 | 1.1 | | | | | |
| 1 | 7.2 | 3.6 | 1.8 | 1.4 | | | | | |
| 1½ | 10.4 | 5.2 | 2.6 | 2.1 | | | | | |
| 2 | 13.6 | 6.8 | 3.4 | 2.7 | | | | | |
| 3 | | 9.6 | 4.8 | 3.9 | | | | | |
| 5 | | 15.2 | 7.6 | 6.1 | | | | | |
| 7½ | | 22 | 11 | 9 | | | | | |
| 10 | | 28 | 14 | 11 | | | | | |
| 15 | | 42 | 21 | 17 | | | | | |
| 20 | | 54 | 27 | 22 | | | | | |
| 25 | | 68 | 34 | 27 | | 53 | 26 | 21 | |
| 30 | | 80 | 40 | 32 | | 63 | 32 | 26 | |
| 40 | | 104 | 52 | 41 | | 83 | 41 | 33 | |
| 50 | | 130 | 65 | 52 | | 104 | 52 | 42 | |
| 60 | | 154 | 77 | 62 | 16 | 123 | 61 | 49 | 12 |
| 75 | | 192 | 96 | 77 | 20 | 155 | 78 | 62 | 15 |
| 100 | | 248 | 124 | 99 | 26 | 202 | 101 | 81 | 20 |
| 125 | | 312 | 156 | 125 | 31 | 253 | 126 | 101 | 25 |
| 150 | | 360 | 180 | 144 | 37 | 302 | 151 | 121 | 30 |
| 200 | | 480 | 240 | 192 | 49 | 400 | 201 | 161 | 40 |

For full-load currents of 208- and 200-volt motors, increase the corresponding 230-volt motor full-load current by 10 and 15 percent, respectively.

* These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, and multispeed motors will have full-load current varying with speed, in which case the nameplate current rating shall be used.

† For 90 and 80 percent power factor the above figures shall be multiplied by 1.1 and 1.25 respectively.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

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Figure 5-11. NEC Table 430-150.

Physical protection for our conductors is determined by using figure 5-12, NEC table 3A, "Maximum Number of Conductors in Trade Sizes of Conduit or Tubing." Start on the left-hand column and find the insulation type you need. Ours was type TW. Moving to the right, find the AWG size conductor calculated for the circuit. Ours was AWG No. 8. The remaining columns to the right are the number of conductors allowed in the corresponding pipe sizes at the top of the table. We need three conductors. The 1/2 inch conduit will only hold two No. 8 conductors. The 3/4 inch conduit will hold four No. 8 conductors. We will plan our physical protection of the door motor circuit using 3/4 inch conduit.

We determine the branch circuit overcurrent protection using figure 5-13, NEC table 430–152. "Maximum Rating or Setting of Motor Branch Circuit, Short Circuit and Ground- Fault Protection Devices." To use this table, find the hangar door motor under the "Type of Motor" column on the left. About a third of the way down is the heading "All AC squirrel-cage and synchronous motors with autotransformer starting." Our motor is under 30 amps and has no code letter. Move across to the far right under the "Inverse Time Breaker" column. Our maximum setting will be 200 percent of the motor's FLC. 200 percent of 27A equals 54A. In objective 246, we listed the standard ampere ratings for fuses and inverse time circuit breakers. The closest size to our 54A calculation without going over is 50 amps.

We would install a 50A breaker in panel A-2 and connect three No. 8 TW insulated conductors in 3/4-inch conduit to our door motor in hangar A. Hangar B has the same motor installation. The only change to the calcul... ...ons is that the hangar B motor feeds from panel A-1.

The compressor motor in hangar A, foldout 2, is 10 horsepower, fed from panel A-2, and the home run shows 3 phase. There are no notes on foldout 2 indicating the type of motor, that is, induction or synchroneous, and no code letter is listed. We must assume the motor is full voltage starting. Do we have enough information to calculate the compressor circuit?

See figure 5-11, NEC table 430–150. A 10 Hp, 3$\phi$, AC-motor on 460V draws 14A.

Using 14 amperes, see figure 5-13, NEC table 430– 152. (Remember polyphase means 3 phase.) Our compressor motor can be found using the key, "FULL VOLTAGE STARTING". We had no code letter and panel A-2 uses inverse-time breakers. Our maximum overcurrent protection, then, is 250 percent of 14 amps or 35 amps.

The conductor must be rated minimum, 125 percent of the motor FLC. 125 percent of 14A = 17.5 A. Using figure 5-9, NEC table 310–16, and TW insulation we would plan for No. 12 copper conductors.

What size conduit do we need for three No. 12, TW copper conductors? Figure 5-12, NEC table 3A, shows 1/2-inch conduit will hold up to seven No. 12 conduc:ors.

The sump pump motor in hangar A is rated 1/2 hp, 220V, 1$\phi$. The motor has a squirrel-cage rotor and code letter A. It is wired with TW copper conductors to a inverse-time breaker. (NOTE: Use figure 5-14 to find FLC on 1$\phi$ motors).



**Table 3A. Maximum Number of Conductors in Trade Sizes of Conduit or Tubing**
**(Based on Table 1, Chapter 9)**

| Conduit Trade Size (Inches) / Type Letters | Conductor Size AWG, MCM | 1/2 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 | 2 1/2 | 3 | 3 1/2 | 4 | 4 1/2 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TW, T, RUH, | 14 | 9 | 15 | 25 | 44 | 60 | 99 | 142 | | | | | | |
| RUW, | 12 | 7 | 12 | 19 | 35 | 47 | 78 | 111 | 171 | | | | | |
| XHHW (14 thru 8) | 10 | 5 | 9 | 15 | 26 | 36 | 60 | 85 | 131 | 176 | | | | |
| | 8 | 2 | 4 | 7 | 12 | 17 | 28 | 40 | 62 | 84 | 108 | | | |
| RHW and RHH | 14 | 6 | 10 | 16 | ~9 | 40 | 65 | 93 | 143 | 192 | | | | |
| (without outer | 12 | 4 | 8 | 13 | 24 | 32 | 53 | 76 | 117 | 157 | | | | |
| covering), | 10 | 4 | 6 | 11 | 19 | 26 | 43 | 61 | 95 | 127 | 163 | | | |
| THW | 8 | 1 | 3 | 5 | 10 | 1·3 | 22 | ·32 | 49 | 66 | 85 | 106 | 133 | |
| TW, | 6 | 1 | 2 | 4 | 7 | 10 | 16 | 23 | 36 | 48 | 62 | 78 | 97 | 141 |
| T, | 4 | 1 | 1 | 3 | 5 | 7 | 12 | .17 | 27 | 36 | 47 | 58 | 73 | 106 |
| THW, | 3 | 1 | 1 | 2 | 4 | 6 | 10 | 15 | 23 | 31 | 40 | 50 | 63 | 91 |
| RUH (6 thru 2), | 2 | 1 | 1 | 2 | 4 | 5 | 9 | 13 | 20 | 27 | 34 | 43 | 54 | 78 |
| RUW (6 thru 2), | 1 | | 1 | 1 | 3 | 4 | 6 | 9 | 14 | 19 | 25 | 31 | 39 | 57 |
| FEPB (6 thru 2), | 0 | | 1 | 1 | 2 | 3 | 5 | 8 | 12 | 16 | 21 | 27 | 33 | 49 |
| RHW and | 00 | | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 14 | 18 | 23 | 29 | 41 |
| RHH (with- | 000 | | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 15 | 19 | 24 | 35 |
| out outer | 0000 | | | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 | 16 | 20 | 29 |
| covering) | 250 | | | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 10 | 13 | 16 | 23 |
| | 300 | | | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 11 | 14 | 20 |
| | 350 | | | | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 10 | 12 | 18 |
| | 400 | | | | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 9 | 11 | 16 |
| | 500 | | | | 1 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | 9 | 14 |
| | 600 | | | | | 1 | 1 | 1 | 3 | 4 | 5 | 6 | 7 | 11 |
| | 700 | | | | | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
| | 750 | | | | | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 9 |

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Figure 5–12. NEC Table 3A.

**Table 430-152. Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices**

| Type of Motor | Percent of Full-Load Current | | | |
|---|---|---|---|---|
| | Nontime Delay Fuse | Dual Element (Time-Delay) Fuse | Instantaneous Trip Breaker | * Inverse Time Breaker |
| Single-phase, all types | | | | |
| No code letter | 300 | 175 | 700 | 250 |
| All ac single-phase and polyphase squirrel-cage and synchronous motors† with full-voltage, resistor or reactor starting: | | | | |
| No code letter | 300 | 175 | 700 | 250 |
| Code letter F to V | 300 | 175 | 700 | 250 |
| Code letter B to E | 250 | 175 | 700 | 200 |
| Code letter A | 150 | 150 | 700 | 150 |
| All ac squirrel-cage and synchronous motors† with autotransformer starting: | | | | |
| Not more than 30 amps | | | | |
| No code letter | 250 | 175 | 700 | 200 |
| More than 30 amps | | | | |
| No code letter | 200 | 175 | 700 | 200 |
| Code letter F to V | 250 | 175 | 700 | 200 |
| Code letter B to E | 200 | 175 | 700 | 200 |
| Code letter A | 150 | 150 | 700 | 150 |
| High-reactance squirrel-cage | | | | |
| Not more than 30 amps | | | | |
| No code letter | 250 | 175 | 700 | 250 |
| More than 30 amps | | | | |
| No code letter | 200 | 175 | 700 | 200 |
| Wound-rotor — | | | | |
| No code letter | 150 | 150 | 700 | 150 |
| Direct-current (constant voltage) | | | | |
| No more than 50 hp | | | | |
| No code letter | 150 | 150 | 250 | 150 |
| More than 50 hp | | | | |
| No code letter | 150 | 150 | 175 | 150 |

For explanation of Code Letter Marking, see Table 430-7(b).
For certain exceptions to the values specified, see Sections 430-52 through 430-54.
* The values given in the last column also cover the ratings of nonadjustable inverse time types of circuit breakers that may be modified as in Section 430-52.
† Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, etc. that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

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Figure 5–13. Table 430–152.

**Exercises (248):**

Use the sump pump information provided above and solve the following problems.

1. What is the full load current rating?

2. What size maximum overcurrent device is required?

3. What type of conductor insulation is used?

4. What size AWG conductor is required?

5. What panel in hangar A feeds the sump pump?

**Table 430-148. Full-Load Currents in Amperes Single-Phase Alternating-Current Motors**

The following values of full-load currents are for motors running at usual speeds and motors with normal torque characteristics. Motors built for especially low speeds or high torques may have higher full-load currents, and multispeed motors will have full-load current varying with speed, in which case the nameplate current ratings shall be used.

To obtain full-load currents of 208- and 200-volt motors, increase corresponding 230-volt motor full-load currents by 10 and 15 percent, respectively.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120 and 220 to 240.

| HP | 115V | 230V |
|---|---|---|
| 1/6 | 4.4 | 2.2 |
| 1/4 | 5.8 | 2.9 |
| 1/3 | 7.2 | 3.6 |
| 1/2 | 9.8 | 4.9 |
| 3/4 | 13.8 | 6.9 |
| 1 | 16 | 8 |
| 1½ | 20 | 10 |
| 2 | 24 | 12 |
| 3 | 34 | 17 |
| 5 | 56 | 28 |
| 7½ | 80 | 40 |
| 10 | 100 | 50 |

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Figure 5-14. Table 430-148.

**249. Given various information on the remaining circuits, calculate problems for size of conductors, physical protection, and protective devices.**

**Remaining Calculations.** The remaining calculations needed on foldout 2 are the motors in the shop areas and the special purpose outlets. The remaining motor loads are:

- Pipe threader 15 Hp 480V 3ϕ FLC 21 amps.
- Jig Saw 15 Hp 480V 3ϕ FLC 21 amps.
- Band Saw 7.5Hp 480V 3ϕ FLC 11 amps.
- Air Handlers 25Hp 480V 3ϕ FLC 27 amps (2 each).
- Lathe 3/4Hp 240V 1ϕ FLC 6.9 amps.
- Heater 1/4Hp 240V 1ϕ FLC 2.9 amps.
- Grinder 1/2Hp 240V 1ϕ FLC 4.9 amps.
- Exhaust Fan 1/2Hp 240V 1ϕ FLC 4.9 amps.
- Drill Press 1.5Hp 240V 1ϕ FLC 10 amps.

The special purpose outlet for the welder is calculated by converting 10 KVA (10,000 volt amps) to amperes. We will use the 3ϕ formula KVA = 1.73 × E × I. Substituting our known values into the formula we can solve for I.

$$I = \frac{10{,}000VA}{1.73 \times 4a80V} = \frac{10{,}000VA}{830.4V} = 12 \text{ amps}$$

Our welder circuit requires 12A per ϕ. To prevent nuisance tripping, we are allowed to install overcurrent protection at 200 percent of the calculated load. 200 percent of 12A = 24A. The closest rated breaker is 25A. The branch circuit conductors would be #10 AWG copper. The physical protection used is 3/4-inch conduit.

The battery charger is calculated using the 1ϕ formula:

$$I = \frac{1000VA}{240V} = 4.1 \text{ amps}$$

AFM 88-15 requires a minimum of No. 12 copper conductors and a 15-amp breaker or branch circuits. We would run 1/2-inch conduit for our circuit in panel C to the battery charger.

The five special-purpose outlets in the break room could be run individually using No. 12 AWG copper conductors in 1/2- inch conduit from panel B-3.

The four special-purpose 480V outlets in hangar A requires No. 12 AWG copper conductors in 4½-inch conduits, run from panel A-2.

Hangar B special-purpose outlets have the same requirements as hangar A, but feed from panel A-1.

Calculating the service and subpanel feeders is normally accomplished by a worksheet. List individual loads down the left side and the subpanels across the top. You can fill in the sheet and then total the lighting load, motor load, and special outlet load for each subpanel.

*Panel C:*

| | |
|---|---|
| Total wattage 1735 divided 220V | = 7.8A |
| Total motor load | = 4.9A |
| 25 percent of the largest motor | = 1.2A |
| Special Purpose Outlet (charger) | = 15.0A |
| Total Calculated Load | = 28.9A |

*Panel B-1:*

| | |
|---|---|
| Total motor load | = 29.6A |
| 25 percent of the largest motor | = 2.5A |
| Total Calculated Load | = 32.1A |

*Panel B-2:*

| | |
|---|---|
| Total wattage 5950 divided 220V | = 27.0A |
| Total motor load | = 4.9A |
| 25 percent of the largest motor | = 1.2A |
| Total Calculated Load | = 33.1A |

*Panel B-3:*

| | |
|---|---|
| Total wattage 1,464 divided 220V | = 6.6A |
| Special purpose outlets (total) | = 100.0A |
| Total Calculated Load | = 106.6A |

*Panel A-1:*

| | |
|---|---|
| Total wattage 11,966 divided 480V | = 24.9A |
| Total motor load | = 41.0A |
| 25 percent of the largest motor | = 6.7A |
| Special purpose outlets (Total) | = 80.0A |
| Total Calculated Load | = 152.6A |

*Panel A-2:*

| | |
|---|---|
| Total wattage 20,383 divided 480V | = 42.4A |
| Total motor load | = 94.0A |
| 25 percent of the largest motor | = 6.7A |
| Special purpose outlets | = 92.0A |
| Total Calculated Load | = 235.1A |

*Panel B:*

| | |
|---|---|
| Total load of Panel B-1 | = 32.1A |
| Total load of Panel B-2 | =33.1A |
| Total load of Panel B-3 | = 106.6A |
| Total load of Panel C | = 28.9A |
| Total Calculated Load (240V) | = 200.7A |

We now convert Panel B to KVA using the formula,

$$KVA = \frac{AXV}{1000}.$$

Substituting our figures,

$$\frac{200.7A \times 240V}{1000} = 48.16KVA.$$

This is our calculated load of the step-down transformer feeding 240 volts to panel B. The next size transformer available is 50 KVA. Operating from 480V, 3φ voltage, this transformer would require 60 amp protection from panel A.

*Panel A (Building Main):*

| | |
|---|---|
| Total motor load | = 54.0A |
| 25 percent of the largest motor | = 6.7A |
| Total load of Panel A1 | = 152.6A |
| Total load of Panel A2 | = 235.1A |
| Calculated load of Panel B | = 60.0A |
| Total calculated load | = 508.4A |

**Exercises (249):**

1. Calculate the FLC of a 25 hp, 3φ induction motor running on 460 volts.

2. Determine the size of branch circuit conductors required for a motor rated at 35 amps. FLC calculate using TW insulation and copper.

3. Determine the size of conduit needed for a 3φ, 3-wire branch circuit, rated at 40 amps, type TW copper.

4. Calculate the size of inverse time breaker required for a motor using the following information. 3φ, 460V, squirrel-cage rotor, 7½ hp, code letter B.

5. Calculate the overcurrent protection for a 3φ, 240V, 15KVA welder to prevent nuisance tripping.

**250. Calculate the service required for an industrial building.**

**Service Calculation.** The service for foldout 2 is based on panel A. The main breaker in panel A must be larger than 508 amps. The next size breaker above 500 amps is 600 amps. This value is larger than the largest TW insulated copper conductors made. (AFM 88–15, Chapter 17, requires that all conductors No. 4 AWG or larger be copper.) Two or more conductors in parallel can be used to carry the higher amperage.

One half of the 600 amps equals 300 amps. The nearest conductor to this figure is 500 MCM Type TW. The service could consist of two sets of four, 500 MCM Type TW conductors in two 3½ inch conduits. However, figure 5-9, states "Not more than three conductors in raceway...." By using four conductors in each conduit, we lost 20 percent of their capacity, or 20 percent of 320 amps. This equals 256 amps per conductor. If we double 256 amps for two parallel conductors, they only have a 512 amp capacity.

Now look at THW insulated conductors under the 500-MCM size. They are rated at 380 amps: 80 percent of 380 is 304. Two 500-MCM conductors de-rated to 80-percent capacity would have a 608-amp potential.

The service for foldout 2 will be calculated with a 600-amp main breaker, two parallel sets of Type THW copper conductors, 500 MCM, and will use two 3½-inch conduits. (NOTE: The above service configuration is one of many possible calculations. Supply conductors could be even smaller parallel sets for ease of handling. They could be run in three or more sets of conduit to avoid the 80 percent ampacity penalty.) The main things to remember in paralleling conductors and using two or more conduit runs are:

- All the conductors must be the same size (cross-sectional area) and approximate length.
- The same type of insulation rating.
- Each neutral conductor, if used, must be run in the conduit with it's corresponding phases.

**Exercises (250):**

1. What size main breaker is required for a calculated 729-amp load?

2. Determine the size of conductors required for a calculated load of 315 amps using Type THW copper.

3. What is the amperage penalty of four type TH, 300-MCM copper conductors in conduit?

4. Calculate the service conductors, conduit and main breaker required for a calculated 3ϕ four-wire load of 460 amps.

## 5-3. Planning and Coordinating Operations

Once an electrical project is designed and engineered, the final outcome is a work order to the shop. The shop supervisor should go through the work order package checking to be sure the job is ready to release and schedule.

We will cover the prescheduling steps the supervisor should follow in two parts: planning the sequence of work operations and coordinating electrical work with other shops.

**251. Given a random list of information on job sequence, put the information in logical order for work accomplishment.**

**Sequence of Work Operations.** The main objective to establish a sequence of work is to eliminate nonproductive time once work begins. A shop supervisor should answer the following questions before scheduling a work order on the AF Form 561, Base Civil Engineering Weekly Schedule:

*a.* Whom do I have available to start a new project?

*b.* How many personnel will be scheduled each day?

*c.* Is anyone on upgrade training that could benefit by being assigned to the project?

*d.* Are all materials in the CE holding area or designated supply point?

*e.* Were substitutions of materials made that will not fit the remaining materials?

*f.* Will secure storage be available at the work site for materials and tools or must we transport them back to the shop each night?

*g.* Are special tools required; if so, are they available and serviceable?

*h.* Is the worksite a secure area, if so; will the electricians need security badges, or will escorts be be provided?

*i.* Will the work site be empty or occupied?

*j.* Will the electricians be required to work after normal duty hours because of noise or traffic?

*k.* Will a power outage be required; if so, how many buildings are affected, who will notify the occupants, and how much lead time is required?

This list is not complete: depending on your base and the mission, you may be able to think of other questions.

Now we move to the worksite. Check the plans with the actual working conditions. Take a few minutes to familiarize yourself with the area. This is the time you follow the planners trend of thought and go through the job mentally. Our description of work could read, "Remodel building 2029 for a new flight simulator installation. A remodel job has two aspects: remove and install."

Follow the planner's task-breakdown sheets and verify what should be removed. Will any equipment or material be reused later? Be sure and note any possible safety problems you could pass on to the crew leader?

**Coordinating with Other Specialists.** You are at the point now where you are confident the job can be completed as planned. Your next step is coordinating with the other shops. This may be done at the regular scheduling meeting or between the shop supervisors on the telephone. The conversation may sound something like this. The electric-shop supervisor calls the equipment section and asks, "When will the trench be cut in the concrete floor to install conduit?" The equipment supervisor says, "Just as soon as the carpenters cut a new double doorway in the rear of the building for access." You find the carpenters are waiting on you to remove electrical conduits along the rear wall so they can cut out the doorway. The metal shop supervisor calls you and wants to use your scaffolding to remove some metal ductwork on the same job. The conversations can go on and on, but the key is communicate. An efficient CE organization runs on communication between branches and shops. When you walk into the scheduling meeting, you will be ready to finalize a coordinated plan of operation.

**Exercises (251):**

1. Sequence the information below from 1 through 10 for work accomplishment.

   a. ___ Available man-hours?
   b. ___ Who will be assigned as work leader?
   c. ___ CE branches communicating.
   d. ___ Weekly scheduling meeting.
   e. ___ Were materials substituted.
   f. ___ Is the worksite a secure area?
   g. ___ Are all materials available?
   h. ___ Are special tools required?
   i. ___ Check the worksite.
   j. ___ Will a power outage be required?

# Circuit Installation with Nonmetallic Cable

CIRCUIT INSTALLATION varies only in the type of structure being worked on. The methods, procedures, or techniques you have studied thus far are preparing you to install interior distribution systems in Air Force facilities. We will discuss two forms of electrical installation in this chapter: non-metallic-sheathed cable and conduit wiring. Mastering these two methods of wiring should qualify you for 90 percent of your installation jobs.

## 6-1. Box Selection and Mounting

Now that you have learned how to read a blueprint and to draw a working sketch, the next step is to start the installation of circuits, according to your drawing. A very important part of the installation will be the selection and mounting of the boxes required for outlets and junctions.

**252. Specify factors that you must consider when selecting boxes for use in interior wiring systems, and calculate cubic-inch area requirement for a given application.**

**Box Selection.** There is no firm requirement that a certain type of box be installed for a specific purpose. The usual practice is to install octagonal boxes for lighting outlets and to install rectangular and square boxes for switches and receptacle outlets. Round boxes are normally installed overhead for lighting purposes, especially where the fixture canopy must cover the box. However, when the need arises because of inside space requirements, wall-surfacing materials used, number of electrical devices to be mounted, or the availability of boxes, almost any box can be used for any purpose.

The size and number of conductors to be installed in a box have a definite impact on the selection of a box. Each conductor in a box must have some free airspace to prevent a buildup of heat. As a result, the more conductors, or the larger their size, the bigger the box must be in which they are installed. The cubic-inch capacity of a box is determined by its length, width, and depth. An increase in one or more of these dimensions will increase box capacity. When gangable boxes are assembled together, box volume is the total of all sections assembled together. Also, when a raised cover or a box extension with volume markings is added to a box, its capacity is added to the volume.

The box to be mounted in each location is selected after the number and size of conductors it will contain are known. In many cases, the usual box for the intended purpose is not adequate. To insure proper airspace for conductors in a box, consult figure 6-1, NEC tables 370–6(a) and (b). These tables list dimensions for common boxes, their cubic-inch capacity, and the maximum permitted number of conductors in wire sizes No. 14 through No. 6. The number of conductors listed does not make allowance for fixture studs, cable clamps, grounding conductors, switches, receptacles, or straps for mounting these devices. One conductor must be deducted from those listed when the box contains one or more fixture studs of cable clamps. Each strap containing one or more devices requires deduction of one conductor.

Also, one conductor is deducted for one or more grounding conductors that enter the box. A conductor that runs through the box is counted as one conductor. Each conductor that terminates in the box counts as one. Fixture wires and conductors that do not leave the box, such as an internal grounding wire, are not counted.

Let's use an example to see how the table works. Two receptacle outlets are to be installed using No. 12 nonmetallic cable. One of the outlets is to be installed as an extension to the other. Device boxes with cable clamps are to be used if possible. The first step is to determine the number of conductors involved in the box that will be wired through. Two conductors plus a grounding conductor enter this box. Also, if a second outlet is to be connected to this one, two conductors plus a grounding conductor must leave the box. If the preceding rules are followed, we have four conductors plus one for the grounding conductors, the equivalent of one conductor for the cable clamps, and the equivalent of one conductor for the receptacle outlet. This gives us an equivalent of seven conductors. In looking at the table for metal boxes in the NEC, no listing is given for seven No. 12 conductors in a device box. There is a listing for eight conductors, which indicates a device box 3½ inches deep is required. Since there will be an equivalent of just five conductors in the device box for the second outlet, the table shows a 2½-inch deep box is adequate. When a 3½-inch box is not available or is too deep, a 2½-inch gangable box can be used by replacing one side with a space expander, as shown in figure 6-2. This expander adds 5 cubic inches to a 2½-inch device box for a total of 17.5 cubic inches. Of course, a 4-inch square box with device cover can be used if a satisfactory device box is not available.

The table does not cover all requirements for conductor space in boxes. Boxes of 100 cubic inches or less not covered by the table, and nonmetallic boxes, are marked with their cubic inch capacity. When these boxes are used, or when conductors of different sizes are installed in the same box, the number of conductors allowed in a box is based on a free airspace requirement for each conductor. The free airspace needed is given in figure 6-1 part (b), "Volume Required Per Conductor." According to the

**Table 370-6(a). Metal Boxes**

| Box Dimension, Inches Trade Size or Type | Min. Cu. In. Cap. | Maximum Number of Conductors | | | | |
|---|---|---|---|---|---|---|
| | | No. 14 | No. 12 | No. 10 | No. 8 | No. 6 |
| 4 x 1¼ Round or Octagonal | 12.5 | 6 | 5 | 5 | 4 | 0 |
| 4 x 1½ Round or Octagonal | 15.5 | 7 | 6 | 6 | 5 | 0 |
| 4 x 2⅛ Round or Octagonal | 21.5 | 10 | 9 | 8 | 7 | 0 |
| 4 x 1¼ Square | 18.0 | 9 | 8 | 7 | 6 | 0 |
| 4 x 1½ Square | 21.0 | 10 | 9 | 8 | 7 | 0 |
| 4 x 2⅛ Square | 30.3 | 15 | 13 | 12 | 10 | 6* |
| 4 11/16 x 1¼ Square | 25.5 | 12 | 11 | 10 | 8 | 0 |
| 4 11/16 x 1½ Square | 29.5 | 14 | 13 | 11 | 9 | 0 |
| 4 11/16 x 2⅛ Square | 42.0 | 21 | 18 | 16 | 14 | 6 |
| 3 x 2 x 1½ Device | 7.5 | 3 | 3 | 3 | 2 | 0 |
| 3 x 2 x 2 Device | 10.0 | 5 | 4 | 4 | 3 | 0 |
| 3 x 2 x 2¼ Device | 10.5 | 5 | 4 | 4 | 3 | 0 |
| 3 x 2 x 2½ Device | 12.5 | 6 | 5 | 5 | 4 | 0 |
| 3 x 2 x 2¾ Device | 14.0 | 7 | 6 | 5 | 4 | 0 |
| 3 x 2 x 3½ Device | 18.0 | 9 | 8 | 7 | 6 | 0 |
| 4 x 2⅛ x 1½ Device | 10.3 | 5 | 4 | 4 | 3 | 0 |
| 4 x 2⅛ x 1⅞ Device | 13.0 | 6 | 5 | 5 | 4 | 0 |
| 4 x 2⅛ x 2⅛ Device | 14.5 | 7 | 6 | 5 | 4 | 0 |
| 3¾ x 2 x 2½ Masonry Box/Gang | 14.0 | 7 | 6 | 5 | 4 | 0 |
| 3¾ x 2 x 3½ Masonry Box/Gang | 21.0 | 10 | 9 | 8 | 7 | 0 |
| FS—Minimum Internal Depth 1¾ Single Cover/Gang | 13.5 | 6 | 6 | 5 | 4 | 0 |
| FD—Minimum Internal Depth 2⅜ Single Cover/Gang | 18.0 | 9 | 8 | 7 | 6 | 3 |
| FS—Minimum Internal Depth 1¾ Multiple Cover/Gang | 18.0 | 9 | 8 | 7 | 6 | 0 |
| FD—Minimum Internal Depth 2⅜ Multiple Cover/Gang | 24.0 | 12 | 10 | 9 | 8 | 4 |

**Table 370-6(b). Volume Required per Conductor**

| Size of Conductor | Free Space Within Box for Each Conductor |
|---|---|
| No. 14 | 2. cubic inches |
| No. 12 | 2.25 cubic inches |
| No. 10 | 2.5 cubic inches |
| No. 8 | 3. cubic inches |
| No. 6 | 5. cubic inches |

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Figure 6-1. NEC Tables 370-6(a) and (b).

table, the volume of space needed in cubic inches per conductor is 2 for No. 14, 2¼ for No. 12, 2½ for No. 10, 3 for No. 8, and 5 for No. 6. As an example, if a box is to contain four No. 10 conductors and two No. 12 conductors, multiply 4 X 2½ and 2 X 2¼. This equals 14½-cubic inches—the minimum size box that can be installed.

**Exercises (252):**

1. Why must a conductor be provided free airspace in a box?

2. How is the space available in a box determined?

3. What is the total volume of the box that results when three switchboxes are ganged?

4. How do you determine whether a box will be large enough for the number and size of conductors it will contain?

5. You have a device box 2½-inches deep that lacks 3 cubic inches being large enough for the conductors to be installed, and there is not enough space to use a deeper box. How can you provide enough space and still use a device box?

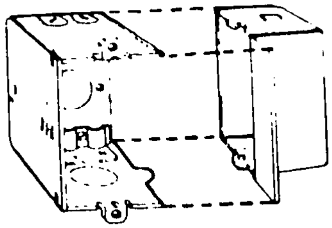

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Figure 6-2. Gangable box and space expander.

6. When wiring is to be done with nonmetallic boxes, how do you determine the size box needed at each location?

7. Determine the cubic inches required in a box for installing a duplex receptacle outlet using No. 10 nonmetallic cable with ground and anchored with a cable connector.

**253. Identify design characteristics of outlet and junction boxes, and cite methods and procedures for installing them.**

**Box Mounting.** Outlet and junction boxes are mounted in a number of ways in either new construction or in an old building. In most cases, boxes in new construction are fastened with nails or screws. Usually, nails are preferred because they are cheaper and quicker to use. Unless the box has a bracket on it, the side of the box must be removed to use screws for mounting. Some of the newer box-mounting brackets have prepunched and formed devices that are driven into wood framing to support the box in the place of nails.

*Nail through box mounting*. One of the simpler boxes to mount is a device box. Boxes without brackets are mounted by putting two 16-penny nails (3½ inches long) through the holes in both sides of the box and then driving them into the wood framing member (stud). Nails that pass through the inside of a box must not be more than a quarter-inch from the bottom (or back) of the box, as shown in figure 6-3. Also, note the markings on the side of the box. These are depth markings that let you easily install the box to project the proper distance from the edge of the stud to offset the thickness of the wall material that will be installed. Another way to mount device boxes with 16-penny nails is shown in figure 6-4. In this case, the nails are outside the box, eliminating the possibility of wiring interference inside. The extension of the box sides, as is done here to provide for nailing, is often referred to as an S bracket mount. The bracket is made so that the nails can be driven in straight or on a slant, depending on whichever is easier. Being able to drive the nails at a slant is especially useful when the stud

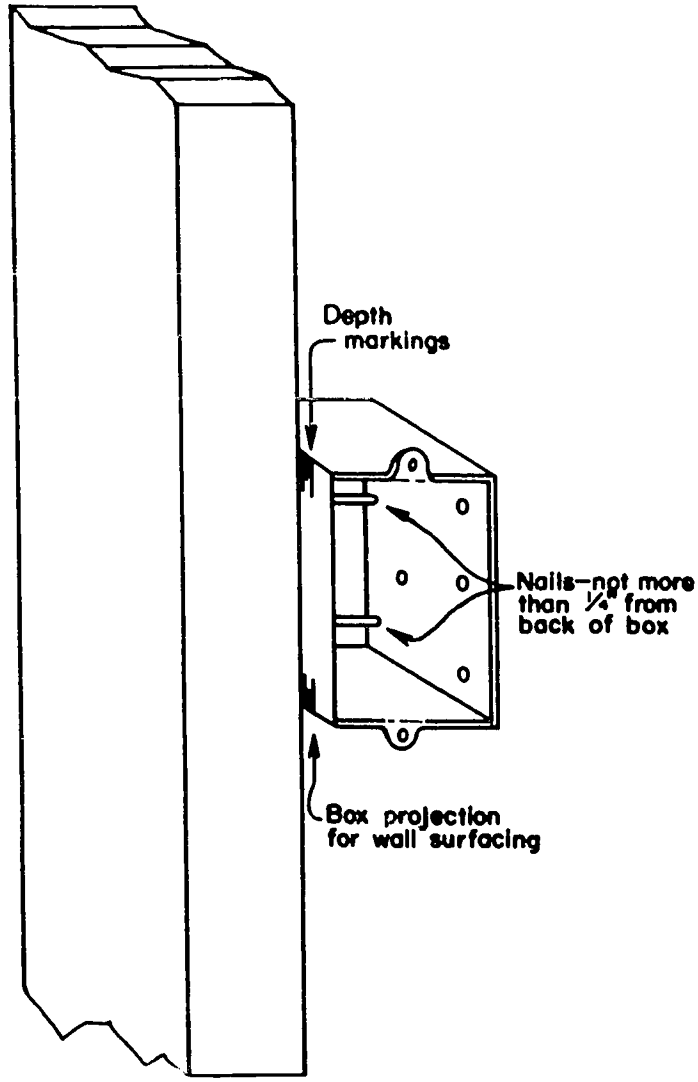


Figure 6-3. Box installed with nails.

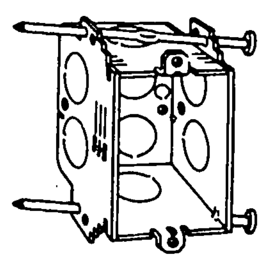

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Figure 6-4. S bracket box mounting.

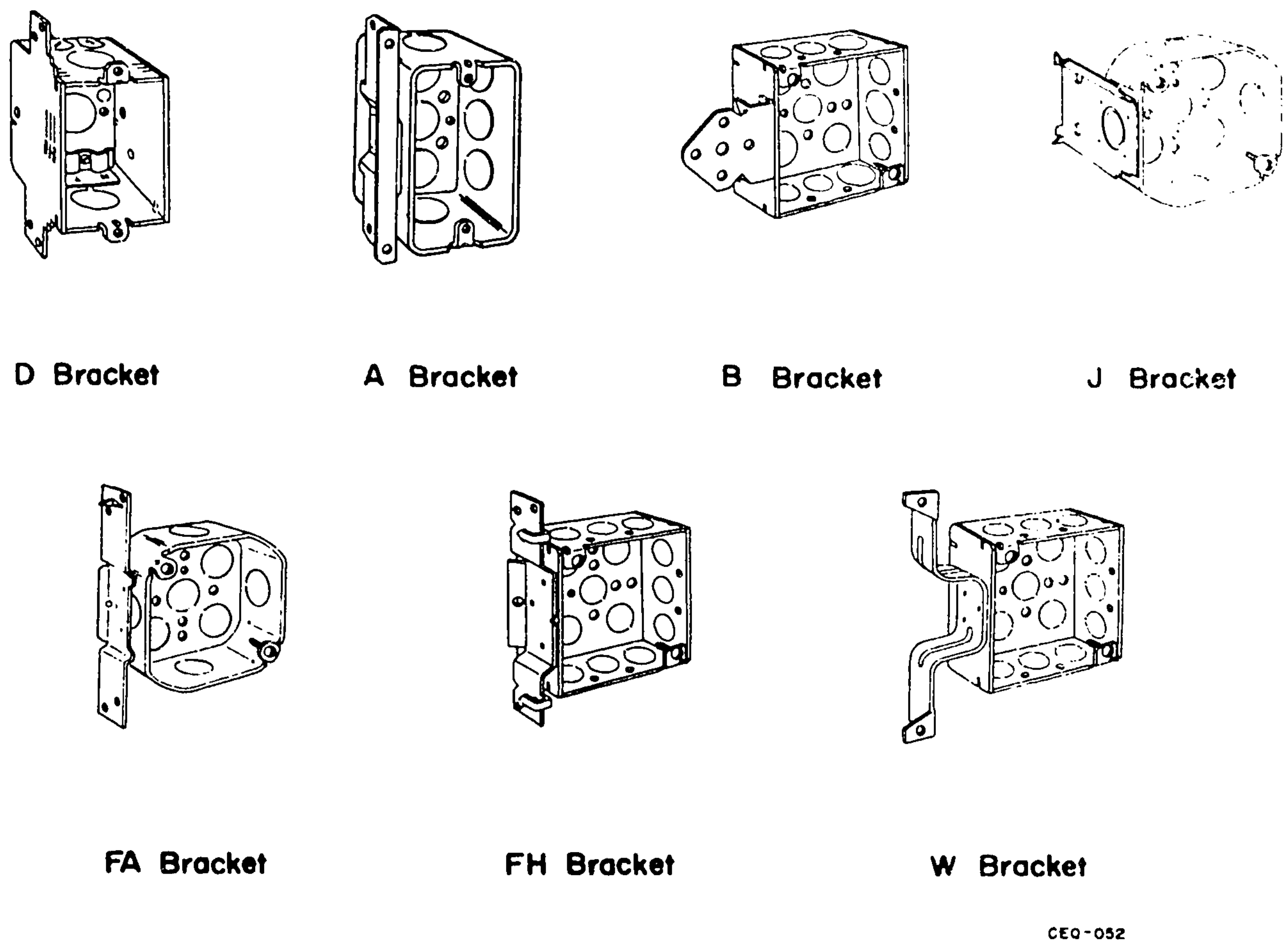


Figure 6–5. Box mounting brackets.

spacing is less than normal. The notches on the front outer ends of the bracket serve as a depth guide for mounting, the same as the markings mentioned before.

*Bracket mounting of boxes.* Many boxes come with attached brackets of various designs. Several of these brackets are shown in figure 6-5. The D bracket illustration is the simplest one of the group and is merely an extended box side. It is nailed or screwed to the stud. It also has notches to serve as an installation guide. The next bracket is the A bracket. As you can see, it is a straight bracket with a turned-over upper edge that fits over the edge (face) of the stud. When nailed from both the front and side, this bracket makes an extremely strong mounting. The A brackets come attached to the boxes at varying distances from their edges to allow for use with different thicknesses of wall material.

The B bracket is made to fasten the box to the face of the stud. It has two spurs that, when driven into the stud, hold the box in place while it is being nailed. The bracket may be attached to the box so that it projects slightly above the edge, as shown in the illustration. This prevents the device cover and its holding screws from causing a bulge when sheetrock is used for the wall surface. B brackets on device boxes are located at various depths to coincide with the thickness of the finished wall. Some B brackets are about twice as long as the one shown. These brackets are suitable for mounting on doorway framing studs to place switches and their cover plates beyond the edge of the door trim. This same bracket may be attached to the end of a device box for the horizontal mounting of a switch or receptacle. End brackets are identified as E brackets.

The J bracket is used the same as any other bracket that is fastened directly to the side of a stud. The holes are slotted to permit the box to be toenailed. The bracket is flush with the edge of the box and has gauging notches for positioning. This bracket has a knockout which allows installation of conduit through the stud into the box. The FA bracket is very similar to the D bracket except the bracket is welded to the side of the box. It also has a positioning spur to assist in holding the box in place while it is being nailed. The bracket is offset from the edge of the box 1/2 inch or 5/8 inch to allow for the wall material thickness. The FH bracket is similar to the FA except it has two barbed hooks that drive into the face of the stud. The bracket is welded flush on square boxes and offset 1/2 inch on device boxes. Driving the barbed hooks into the stud face and nailing the side makes a very rigid mount. The W bracket is fastened to

both the face and side of the stud to provide a rigid mount. Since it stands the box off to the side of the stud, it is used to provide clearance between switches and switchplates and doorway trim, as does the long B bracket.

*Box mounting on metal framing*. Much modern construction makes use of metal framing members. Primarily you are concerned with the studs and the doorframing (door buck). Boxes can be attached with sheet-metal screws or machine bolts and nuts. However, special attaching devices are available. A special anchor, as shown in figure 6-6, provides a quick, simple method of installing a box on the doorframing. This anchor allows the box to be adjusted in all directions; that is, toward or away from the frame, the depth from the outside wall surface, and up or down as needed. The nut on the bolt shown in the figure holds the bracket to the anchor and must be loose while the anchor is installed. The anchor itself consists of a flat head bolt with a screwdriver slot and a threaded channel. The channel comes in two sizes—one for narrow door bucks not over 4 inches wide and a second for door bucks up to 7 inches wide. The anchor is set in place by inserting it in the frame channel with the flat head of the bolt toward the door-stop channel and the threaded channel under the lips of the door buck. The anchor is locked in place by inserting a screwdriver in the slot of the bolt and turning it clockwise until tight. As you can see in the figure, the bracket is adjustable and is held in position by the tightened nut on the bolt. The box is adjustable toward or away from the door buck and is attached to the bracket with two machine bolts and nuts.

Spring metal clips provide a quick and easy way of mounting boxes onto metal studs. The same clip will work on studs of more than one design and size, such as 1 5/8 - to 3 5/8-inch, C-channel studs and truss-type studs. They are designed to mount square boxes with cover plates and to permit device boxes to be flush-mounted with various thicknesses of wall surfacing. A spring metal clip is shown at the left of figure 6-7. To mount a box, tap the clip over the open edge of the box. Then tip the box so that the upper prong slips behind the face of the stud, as you can see at the right of figure 6-7. Press the lower prong back with the thumb until it slips behind the stud face and locks the box in place. The box can be moved up or down on the stud easily by releasing the spring tension. Boxes can also be attached to metal framing members with sheet metal screws or machine bolts and nuts.

*Box mounting between framing*. At times, boxes must be mounted between the building supports instead of directly on them. This is particularly true of ceiling lights where the joists do not coincide with the spot where the light is to be placed. In such cases, boxes must be mounted on a separate support attached to the structure. These supports may be purchased in the form of bar hangers or metal straps or they may be constructed from metal straps or wooden strips.

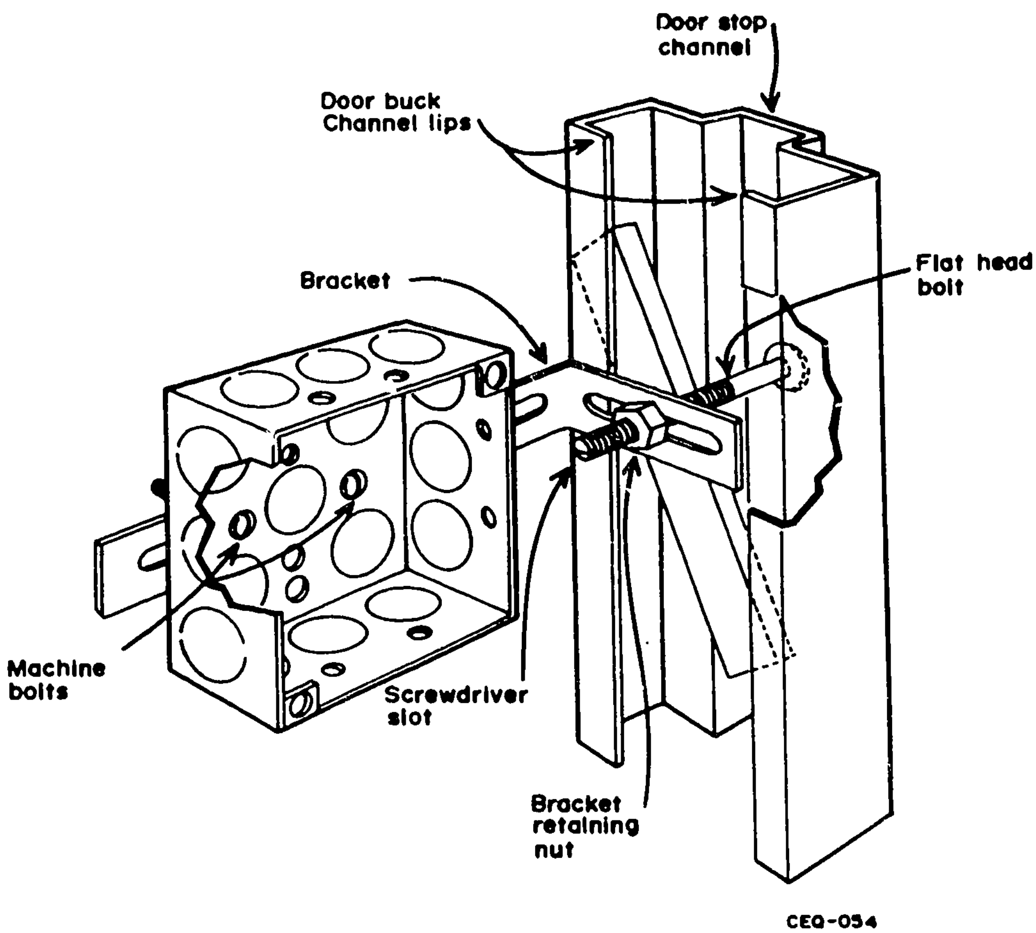


Figure 6-6. Box mounting on metal door buck.

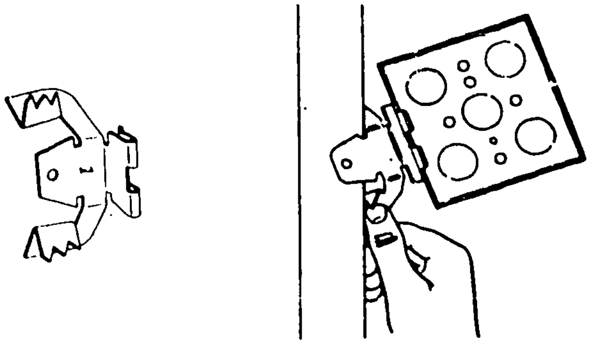

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Figure 6-7. Box mounting on metal stud with spring clip.

Figure 6-8 shows two typical bar hangers and two metal strap supports. You can see that one of the bar hangers includes a fixture stud that also serves to support the box when it is installed through the knockout in the box bottom. The other bar hanger supports the box by means of a clamp installed through the bottom knockout. Bar hangers with boxes already attached are available. Bar hangers come in different lengths with each having a range of adjustment to fit spaces of varying widths. Bar hangers are fastened in place by nails driven into the side of the joist or stud. Sheet metal screws or machine bolts and nuts are substituted for nails when metal framing is involved. Metal straps may have fixture studs or may have slotted mounting holes so that the box may be attached with machine bolts and nuts. Strap supports come in different lengths with several nail holes in each end to fit various width spaces. Strap supports are nailed to the face of the joist or stud. They have different offsets to fit different box depths or installation needs.

Metal strap supports can be made similar to the manufactured one shown in figure 6-8. Hole locations should be determined and holes drilled as needed for the specific installation being made. Wood supports can be made in a number of ways. About the simplest form is shown in figure 6-9. It consists of a piece of 1" x 4" lumber cut to length to fit between the joists and nailed in place. You need to allow for the depth of the box plus the thickness of the ceiling material when positioning the board for nailing. In some cases, two 1" x 4"s may be nailed up with the wide dimension perpendicular to the joist or stud faces and the box mounted between them. Sometimes the ends of the 1" x 4" support is nailed to 1" x 4" x 4" blocks which, in turn, are nailed to the joists.

*Box mounting in existing structures.* A completely different method of box mounting is required when a concealed extension is to be made to an existing circuit or a new concealed circuit is to be added in an existing structure. The procedures discussed here pertain to mounting boxes in hollow walls; that is, walls such as sheetrock or plaster on studs. Boxes must be equipped with "plaster ears" to assist in anchoring them in place. One method of hollow-wall mounting is shown in figure 6-10. This method uses two sheet metal brackets to hold the box in place. The first step for this type of mounting is to locate and cut the mounting hole. After the hole is cut, hold the box in place in the hole with the plaster ears against the wall. Slip a bracket with the fins pointing out, long end first, between the box and the wall. Slide the bracket up until the short end clears the hole. Push the short end into the hole and slide the bracket downward to center the fins with the box. Bend the fins tightly over the box edge and down against the inside. Repeat these steps for the second bracket. The box should now be held firmly in place.

A second method of mounting a box in a hollow wall makes use of clamping devices attached to the box sides as illustrated in figure 6-11. These boxes usually come with a stiff paper template to outline the hole that must be cut into

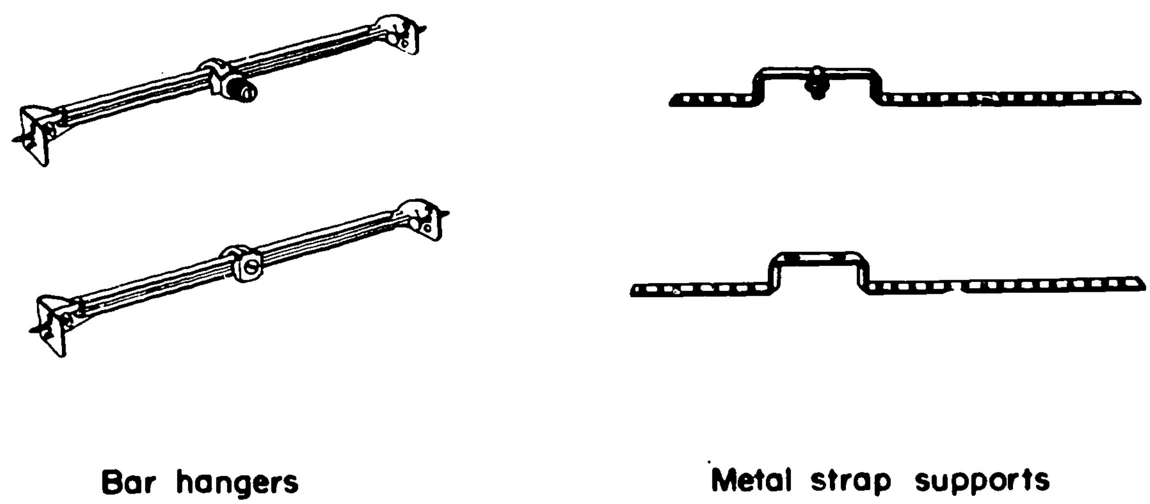


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Figure 6-8. Box supports.

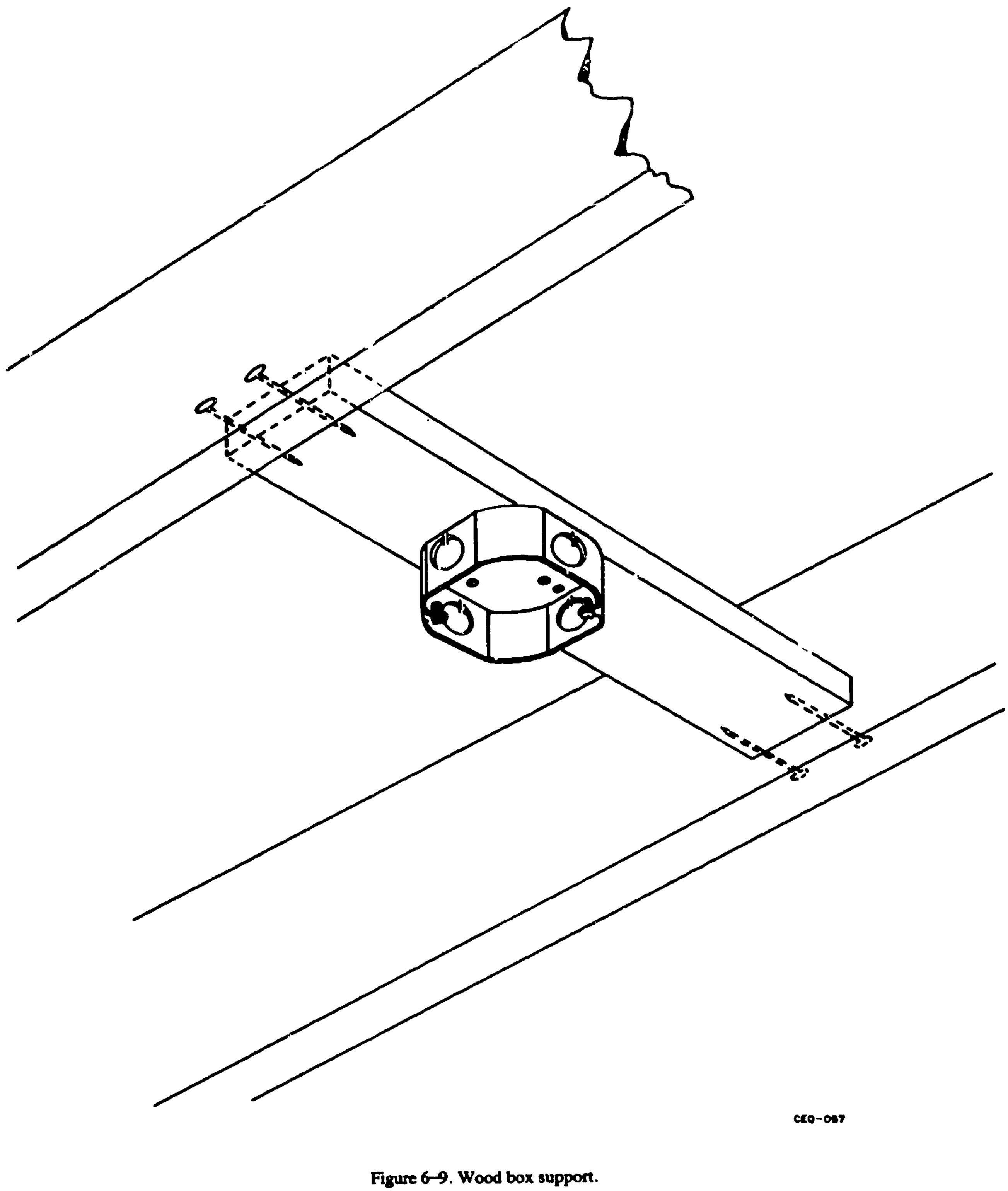



Figure 6–9. Wood box support.

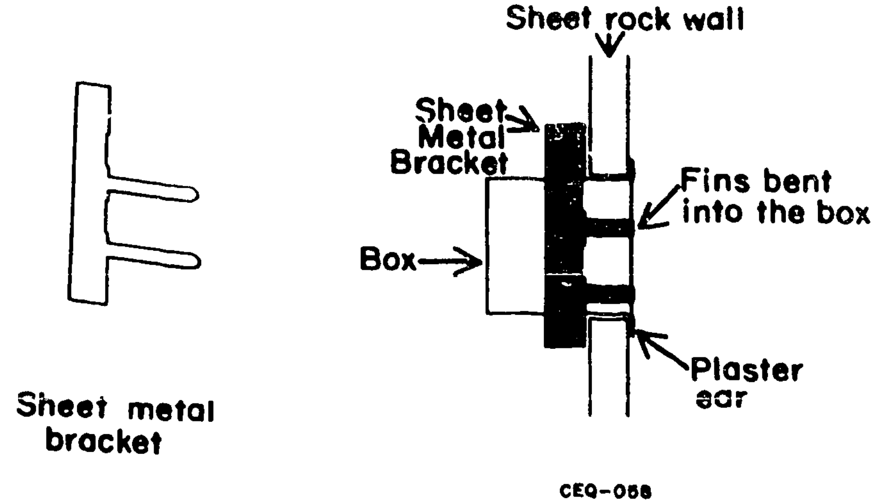



Figure 6–10. Bracket support of box in hollow wall.

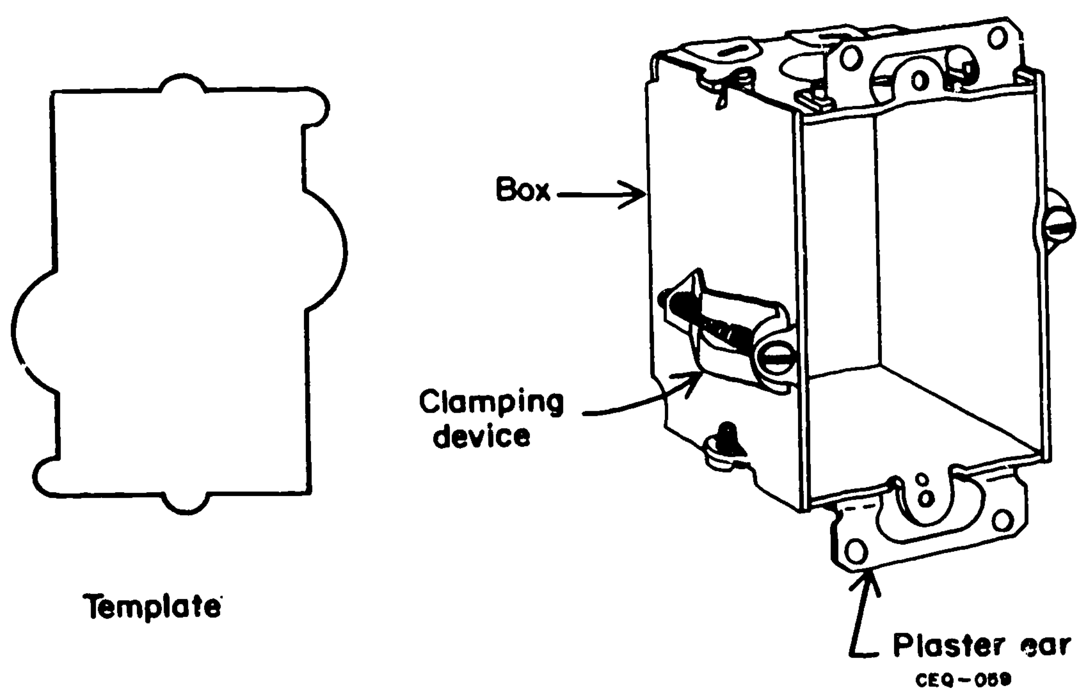



Figure 6–11. Box with hollow wall clamps.

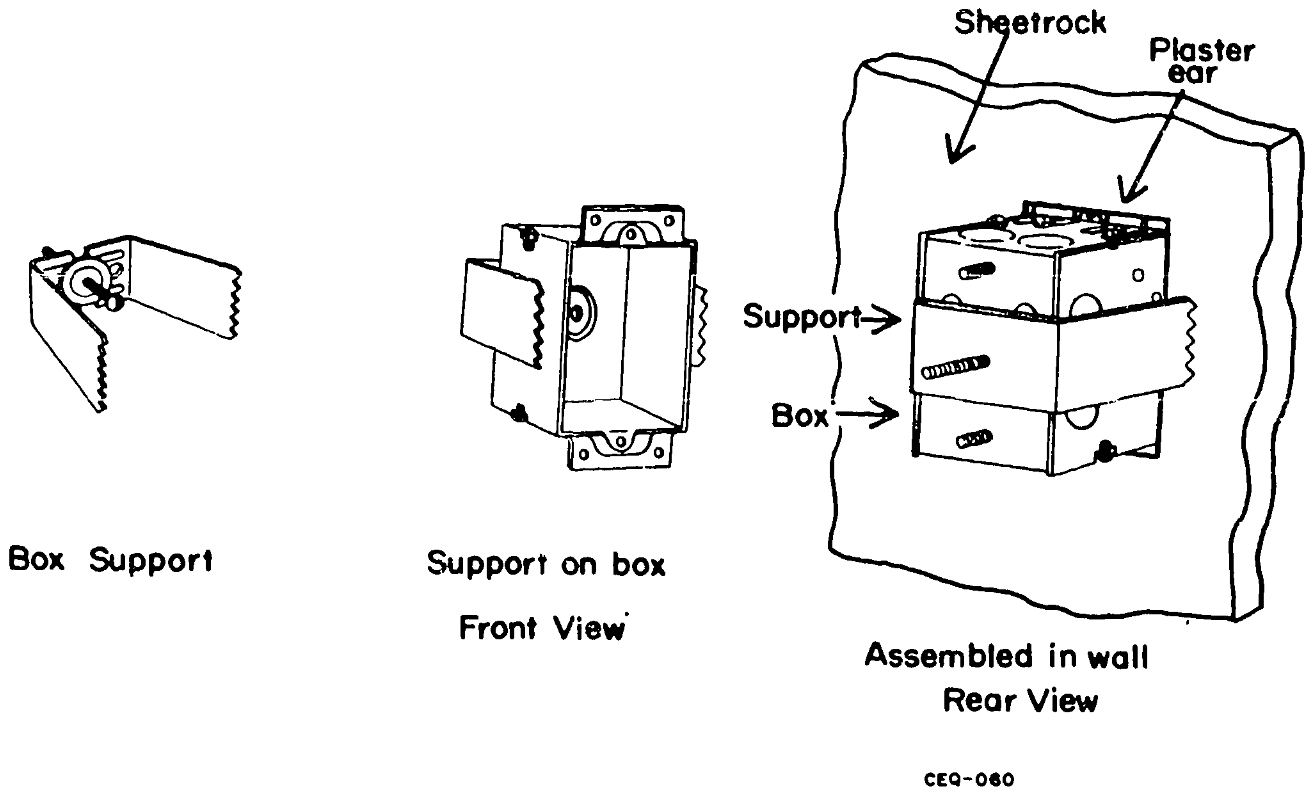



Figure 6–12. Box support for hollow wall.

the wall. If you do not have a template, put the box against the wall and draw around it. Be sure you do not include the plaster ears in your drawing. Cut the hole as indicated. Slip the box into the hole and tighten the clamping screws until the box is firmly anchored. One variation of this method works quite well with a lath and plaster wall. The box has cleats on the side that unfold when the screws are tightened to clamp behind the lath and support the ends that were cut when the hole was made.

A third means of fastening a box in a hollow wall uses a support that is added to the box through the knockout in the back. The application of this support is shown in figure 6-12. After the knockout is removed, assemble the support to the box by inserting the bolt with the retaining washer through the knockout hole. Thread the bolt into the support. Push the box into the prepared hole and press on the bolthead until the ends of the support spring clear on the inside. Tighten the bolt with a screwdriver until the box is held securely in place.

*Box mounting heights and location.* There are no specific requirements for mounting boxes at a certain height. Mounting may be at any convenient height that meets the need for which the box is being installed. All boxes for the same purpose should be mounted at the same height. In some extreme cases, receptacle outlet boxes have been mounted in the wall parallel to the floor and just high enough to permit the cover plate to be installed. This type of installation requires that an allowance be made for the base finishing material, as well as for the wall material when box depth is set. Receptacles set against the floor are hard to use and are hazardous in places where floors are mopped.

Heights for receptacle outlets and switches are usually given in the plans. The measurement may be from either the subfloor or the finished floor and may be to the bottom of the box, the center of the box which is probably the most common, or the top of the box. The most popular height for receptacle outlet boxes in the living areas of a house is 12 inches from the floorline to the center of the box. A good many electricians mark their hammer handles to use as a guide for installing outlet boxes at the proper height. Any number of other guides, such as a rule or a notched stick, can be used.

It is fairly common practice to mark the exact location of each wall-mounted box on the studs throughout the building before mounting begins. A lumber crayon, carpenter's pencil, or felt-tip pen that makes an easily seen mark should be used. An arrowhead is used to show where the center of the box is to be placed. The arrowhead also points to the side of the stud where the box will be put. As an added convenience, symbols may be marked near the arrow to indicate the type of device to be installed. Some examples might be XX for a duplex outlet, SS for two single-pole switches, S3 for a three-way switch, or XR for a range outlet.

Switchboxes and outlet boxes for laundry and utility rooms and garages are normally set 4 feet above the floor. This height is often increased 4 to 6 inches when some type

of wainscotting or paneling 4 feet high is to be included as part of the wall. Boxes for outlets over countertops are usually installed about 44 inches from the floor. This measurement can vary a few inches up or down, depending on the height of the back-splash panel. Installing boxes without considering the splash panel could cause you to have boxes that overlap different wall surface levels.

Ceiling boxes are located by a completely different method of measurement. Most rooms have at least one ceiling light located in the center of the room. A number of ways can be used to find the spot to mount this light box. One way is to use a rule or tape to find the halfway point across one dimension of the room and mark it as shown in sketch A of figure 6-13. Make a second measurement across the same room dimension and mark the halfway point. Connect the two marks. Measure the other room dimension to find the center and mark it on the preceding line. This point is the place for the ceiling light box. Sketch B of figure 6-13 shows another way to spot the ceiling box. Run diagonals with string from opposite corners of the room. The point where the diagonals cross is the room center. Sometimes the position of the box is laid out on the subfloor. The point is then transferred to the ceiling by use of a plumb bob (a pointed weight on a string). When held by the string at the level of the ceiling joists with the point of the weight over the desired location, the top of the string will be at the spot that the box is to be mounted.

Many rooms require multiple ceiling lights. If only two lights are involved, measure half the length of the room and then run diagonals for each half, as indicated in sketch C of figure 6-13. This gives you the location for each light. A room that is to be lit with a row of lights will have them installed along the centerline. The lights should be spaced so that the lighting is as uniform as possible. You can determine the spacing by dividing the length of the room by the number of lights. This figure is the space that is to be left between any two adjacent lights. The light at each end of the row is placed at half the preceding distance from the wall. This spacing is shown in sketch D of figure 6-13. If you take another look at sketch C, you will see that the space from the end walls to the lights is also half the space between the lights.

**Exercises (253):**

1. What is the main disadvantage in using screws to mount boxes that do not have brackets?

2. Briefly describe the mounting procedure for an outlet box without mounting brackets when the wall will be covered with 1/2-inch sheetrock.

3. When nails used for mounting a device box extend from side to side but are outside the box, what type of mount is used.

4. In what cases is it advantageous to be able to drive nails through box brackets at a slant?

5. What is the difference in mounting procedures between a D bracket and an A bracket?

6. When using A bracket box mounts, how do you allow for different thicknesses of wall-surfacing materials?

7. How is a box with a B bracket mounted?

8. A square box with a B bracket is to be installed for a receptacle outlet. What prevents the device cover with its retaining screws from causing a bulge in the sheetrock?

9. When using a box with a B bracket for switch installation, how do you insure the switchplate will not overlap the door trim?

10. What type of box bracket should be used if conduit is to be brought through the mounting stud into the box?

11. Why does an FH box bracket make a more rigid mount than an FA bracket?

12. When is a box with a W bracket used in preference to one with an FH bracket?

13. Indicate in the space provided which of the following statements concerning mounting boxes on metal door framing with an anchor and bracket assembly are true (T) or false (F).

_____ a. The anchor is adjustable to any height.
_____ b. Several size anchors are needed to allow for different wall thicknesses.
_____ c. The nut on the anchor bolt fastens both the anchor and the box bracket in place.

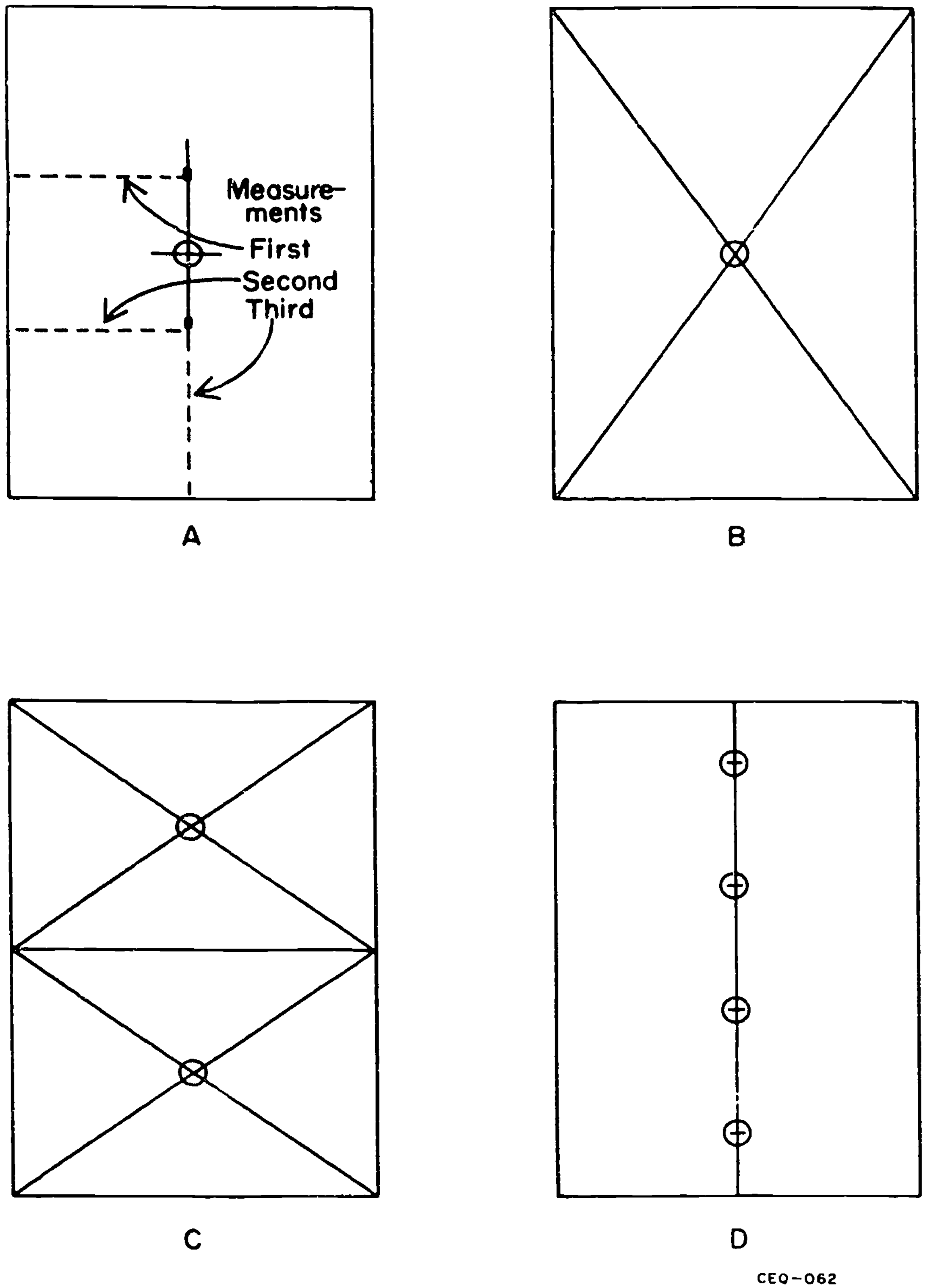



Figure 6–13. Location of ceiling lights.

_____d. Both a screwdriver and wrench are needed to fasten the anchor in place.
_____e. The anchor bolt nut permits the box to be adjusted so it will be flush with the finished wall.
_____f. The box can be moved away from the doorframe by loosening nuts on the box mounting bolts.
_____g. Turning the anchor bolt counterclockwise tightens the anchor in place.
_____h. Machine bolts and nuts are used to attach the box to the mounting bracket.

14. Describe a procedure for mounting a box on a metal stud.

15. A box has been mounted on a metal stud with a spring clip. You discover it is 4 inches too high. What action should you take?

16. Name four ways that boxes can be mounted between ceiling joists.

17. In what two ways may boxes be attached to a bar hanger?

18. Spacing between framing members is not always uniform. How do you compensate for these varying widths when installing boxes on bar hangers?

19. Describe the installation of a ceiling box between framing members using a wood support.

20. State the height requirements for mounting boxes in a wall.

21. What are two disadvantages of having receptacle outlets mounted against a hard-surfaced floor?

22. What is the most common height for mounting receptacle outlets in a house?

23. Name three common devices used to measure the height for mounting outlet boxes in the living areas of a house.

24. Describe the procedure used if the location of all boxes is to be laid out before mounting begins.

25. List places where boxes are normally mounted 48 inches above the floorline.

26. When would switchboxes be mounted about 4½ feet high?

27. What is the normal height for outlet boxes over countertops?

28. How can a tape be used to locate the centerpoint of a room for a ceiling light?

29. How can you locate the spot for a single ceiling light without using a tape?

30. What is a simple way of finding the box location when a room is to have two ceiling lights?

31. A room 25 feet long by 15 feet wide is to be lighted by a row of three lights down the center. How far apart should adjacent lights be? How far from the wall should the end light be?

32. Enter T or F in the spaces provided to show which of the following statements regarding the mounting of boxes in hollow walls are true or false.

_____a. The box support is forced into the wall by unscrewing the box-support retaining screw.
_____b. A template is especially useful for outlining the hole for a box with clamping devices.

——c. Bend the sheet metal bracket fins over the outer edge of the box to anchor it in place.
——d. A hole must be drilled in the bottom of a box to mount a box sup t.
——e. Boxes with retaining leat clamps are particularly good for ounting in lath and plaster walls.
——f. A box support anchors the box in place by expanding against the sides of the mounting hole.
——g. Boxes with clamping devices are removed easily by loosening the device screws.
——h. Two sheet metal brackets are needed to mount a box by this method.
——i. Plaster ears are used mainly to prevent damage to plaster or sheetrock.
——j. Clamping devices clamp behind the sheetrock when the device screws are tightened.
——k. Sheet metal brackets are installed by inserting the short end first.
——l. Two screws in each plaster ear will provide adequate anchorage for a box.
——m. Select the box to be used before cutting the mounting hole in the wall.

## 6-2. Nonmetallic Sheathed Cable Wiring

Nonmetallic sheathed cable is a low cost way to wire buildings where its use is permitted by the NEC. The ease with which circuits can be installed and the low cost of the cable when compared to the cost of materials required by other means make the use of nonmetallic cable quite attractive.

**254. Specify the construction features and marking of nonmetallic sheathed cable, and cite permitted uses.**

**Nonmetallic Sheathed Metal.** Nonmetallic sheathed cable is more commonly called nonmetallic cable, NM cable, or Romex. Nonmetallic cable consists of two or three insulated conductors in an outer sheath. It may have an added insulated or bare conductor to be used as an equipment ground. The outer sheath is made of a moisture-resistant, flame-retardant, nonmetallic material either of thermoplastic or treated braid.

Nonmetallic cable has copper, aluminum, or copper-clad aluminum conductors. Copper conductors used in cable range in size from No. 14 to No. 2 AWG. The size of aluminum conductors is from No. 12 to No. 2 AWG. Nonmetallic cable is required to have markings on its exterior with specific descriptive information spaced not more than 24 inches apart. The information required must show the manufacturer's name or trademark, maximum working voltage, wire size, and cable type. Most cable is also marked to show the number of conductors and whether it has a ground.

Nonmetallic cable comes in two types: NM and NMC. Type NM cable has a flame retardant, moisture resistant cover. Its use is permitted in one- and two-family dwellings and other structures that do not rise more than three floors above grade. It can be installed for both exposed and concealed work in locations that are usually dry. Type NM cable can be placed or fished through air voids in masonry block or tile walls that are not subject to too much moisture or dampness. It must not be used where corrosive fumes or vapors are present. It cannot be embedded in masonry, concrete, adobe, fill, or plaster; nor can it be run in shallow grooves in these materials and plastered over.

Type NMC cable is corrosion resistant. Its covering is flame retardant, moisture resistant, fungus resistant, and corrosion resistant. It can be used in the same places as type NM cable, plus moist, damp, and corrosive locations. These locations include outside walls of masonry block or tile. Neither type NM or NMC cable is to be used as service entrance cable.

**Exercises (254):**

1. Briefly describe the construction of nonmetallic sheathed cable.

2. What are two characteristics of the outer covering of nonmetallic cable?

3. Describe the conductors found in nonmetallic cable.

4. What markings are normally found on nonmetallic cable?

5. How does type NMC cable differ from type NM cable?

6. In what types of buildings may NM cable be installed?

7. Where in a building may type NM cable be installed?

8. Where may type NMC cable be used?

**255. State procedures for installing circuits with nonmetallic cable.**

**Installation.** Installation of electrical circuits with nonmetallic cable is fairly simple. It is usually done in two stages, which are called roughing in and finish work. Roughing in is the work done before the walls and ceilings are put in place, and finish work is just what it implies, the finishing up. (The latter will be covered in the following section.) The main objectives in roughing in are to get the circuits routed properly, to reduce the chance of damage to the cable during installation, and to reduce the chance of damage while the structure is being finished or during later modifications.

*Routing circuits.* Quite often, the new work that you will do in the Air Force will not involve an entire structure. For this reason, you will not always get a complete floor plan of the structure in which the work is to be done. Usually a simplified floor plan, such as the one shown in figure 6-14, is provided. A look at the figure shows you that it does not have much detail. It shows the general location of the outlets and switches, and how the cable is to be routed. The exact spot where each outlet and switch is to be put is determined by requirements of the NEC and the experience of the electrician unless specific directions are given.

A straight line is the shortest distance between two points. This principle is used a great deal of the time when routing NM cable to install the circuits. Cable is run from box to box by the shortest route unless there is a good reason not to. Such routing does not always look as neat as it might, but it keeps the cost of material and labor down. Since most wiring is concealed, it is not often seen anyway.

*Attic circuits.* Most circuits in a one-story residence are run overhead. That is, they run up from the distribution panel to the ceiling and then spread out across the ceiling area. Take another look at figure 6-14. This area is called the attic or roof space, depending on the vertical space under the roof. Each circuit from the panel has to end in some type of box. The box may be a junction box, a ceiling outlet, or a wall outlet. Of course, in the case of the first wall outlet on a circuit, the cable must be run down the wall from overhead.

Cable must be fastened in place to support it and to keep strain off boxes and connections. It must be anchored within 12 inches of a box, cabinet, or fitting and at points no more than 4½ feet apart between boxes. NM cable is usually attached to wood framing members by means of staples. Do not drive the staples in tight enough to damage the cable.

Cables may run in any direction in the attic to get to the first box and between boxes on the same circuit. The cables may be run across the ceiling joists at right angles or on a diagonal line. Some cables will run parallel to the joists. Figure 6-15 shows both a diagonal and a parallel cable run. Note that the diagonal cable is stapled at every other joist. This is done to keep from exceeding the 4½-foot support requirement. Cable run at right angles can be stapled at every third joist (this assumes joists are on 16-inch centers). Also, note that the cable paralleling the joist is attached to the side of the joist. This arrangement protects the cable from damage. Cables on top of the joists must be protected by stout guard strips that are at least as high as the cable. These strips are shown in figure 6-16. Attics accessible by stairs or a permanent ladder require guard strips for all cable that is on top of the joists. When access to the attic is by a scuttle hole, guard strips are needed only within 6 feet of the scuttle hole.

Some cable in the attic or roof space may be fastened to the rafters or studs. It may be run through, be attached to the sides, or be run across the face of the rafters or studs. Cable runs at an angle across the face of rafters or studs within 7 feet of the floor or floor joists must be protected with sturdy guard strips the same as when they are attached to joists. Attics not accessible by stairs or a permanent ladder need guard strips for such cable only within 6 feet of the scuttle hole.

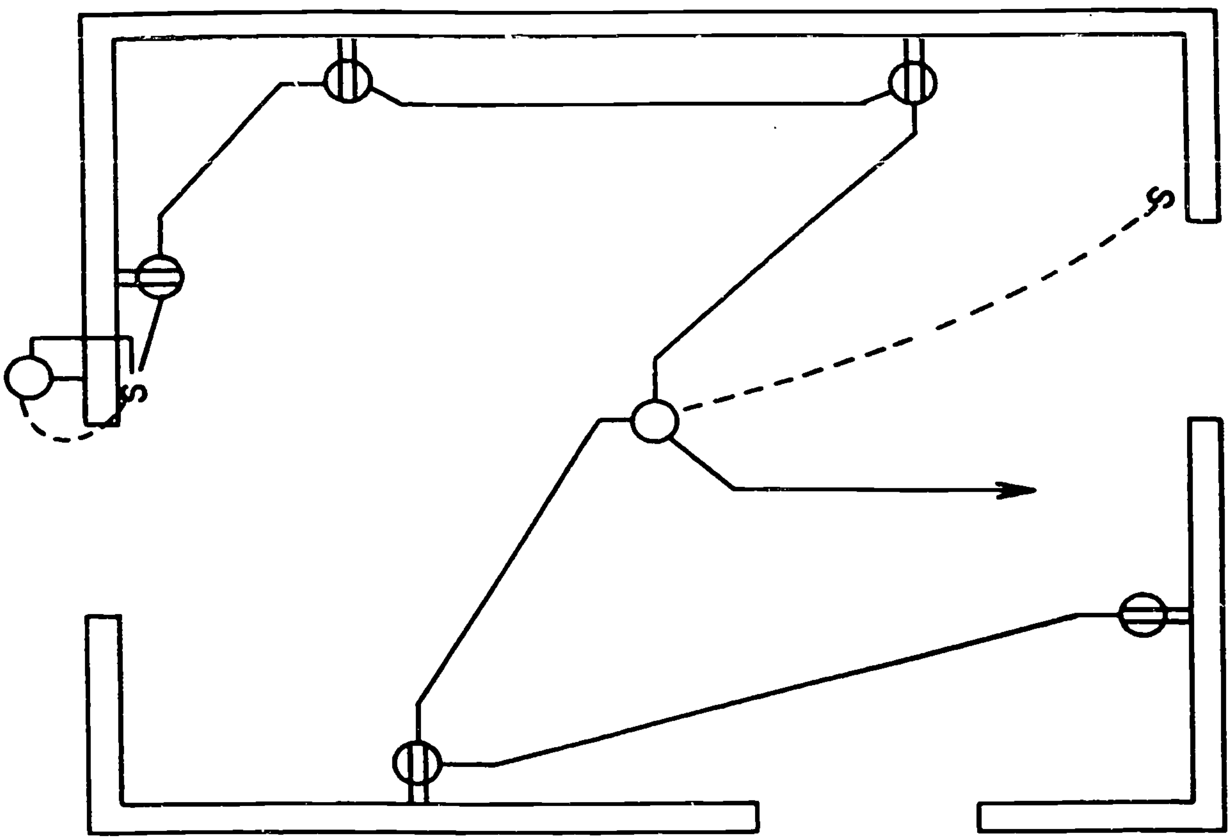
*Unfinished basements.* Cable installed in unfinished basements is partially affected by size. Cable consisting of two No. 6 conductors or three No. 8 conductors may be run on the underside of the joists without further protection. Smaller cable crossing ceiling joists at an angle must be passed through holes in the joists or attached to a running board, as in figure 6-17. A running board provides a firm support and helps to prevent damage to the cable.

*Exposed circuits.* Cable is installed in exposed locations at times. A good example would be a switch leg or an outlet installed in an unfinished basement. The cable should be installed to follow the surface of the building finish closely or be installed on a running board. Figure 6-18 shows two ways that nonmetallic cable can be mounted on studs that are not to be covered. The view on the left shows how the cable would be run down the side of the stud to a box that will be mounted flush with the stud face. When the box is to be mounted on the face of the stud, the cable runs down the face.

Notice that the cables shown in figure 6-18 are not stapled to hold them in place. They are held with cable straps like the ones shown in figure 6-19. The two straps shown at the left are used with oval-shaped cable. The other two straps are used with round cables that have No. 8 or larger conductors. The round straps are designed to be used with electrical metallic tubing, but work quite well with cable. Cable straps are used where cable is mounted on a smooth wall surface and quite often wherever else cable is exposed. Straps give a more finished appearance and provide more support than do staples.

Now, take another look at figure 6-18. Note the bends in the cable. As you can see, they are not sharp bends but curves. A bend in nonmetallic cable must never be made with a radius that is less than five times the cable diameter. Larger radius bends prevent damage to the protective cover on the cable.

Exposed cable installed on finished building surfaces is normally attached directly to the surface, as shown in figure 6-20. Where cable passes through a floor, it must be protected to at least a height of 6 inches above the floor by rigid or intermediate conduit or pipe, as indicated at the left in figure 6-20. Exposed cable that is apt to be damaged due to its location or the activities that are performed in the area must be protected. This protection can be provided with conduit, pipe, or guard strips. The center illustration in figure 6-20 shows the use of a piece of conduit to protect the



Conductor run to panel (2 wires concealed)

Branch circuit in wall or ceiling (2 wires concealed)

Switch leg to light (2 wires concealed)

Duplex receptacle outlet

Ceiling outlet

Wall outlet

S Single pole switch

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Figure 6-14. Simplified wiring floor plan.

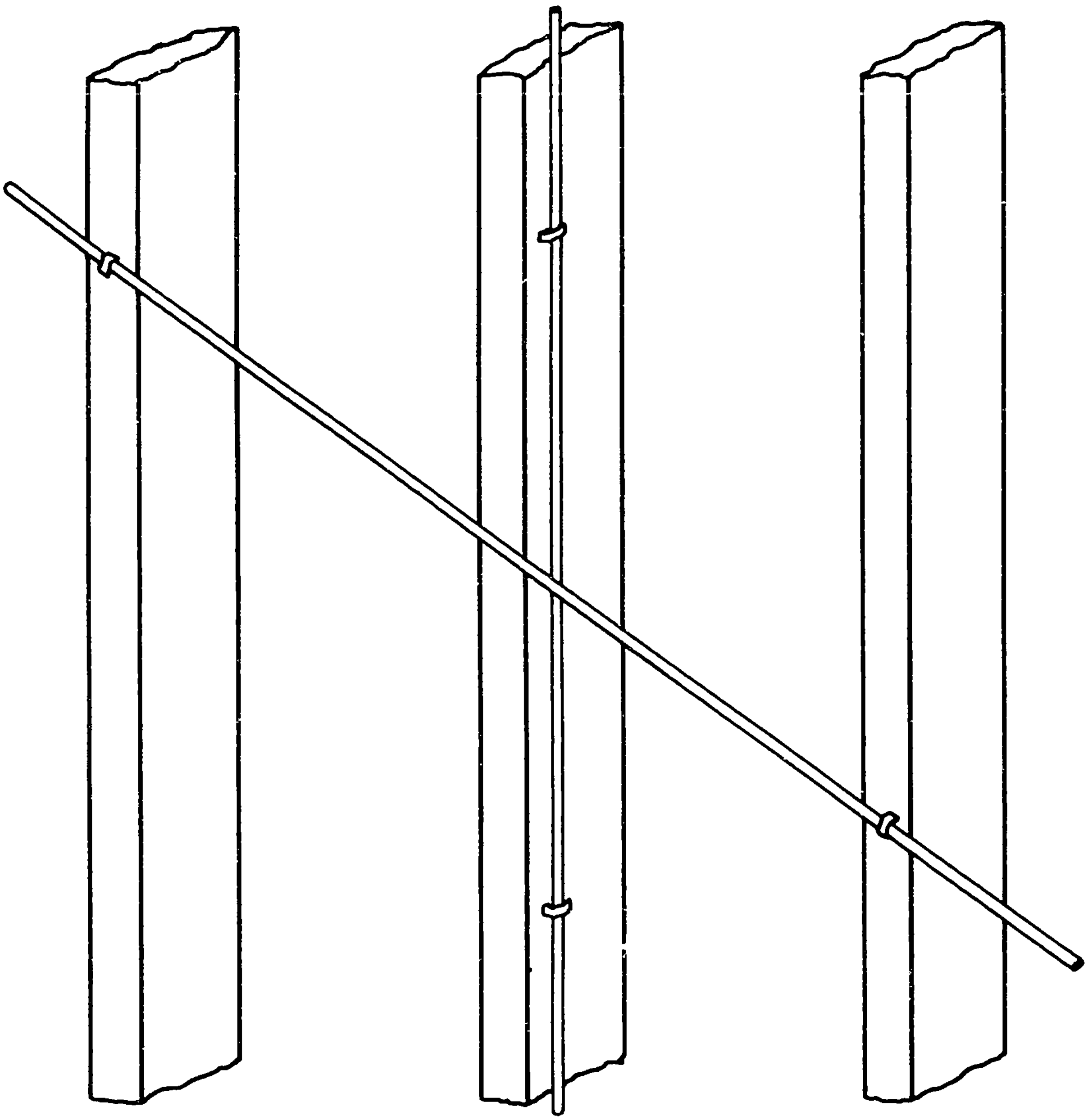


Figure 6–15. Running nonmetallic cable on ceiling joists.

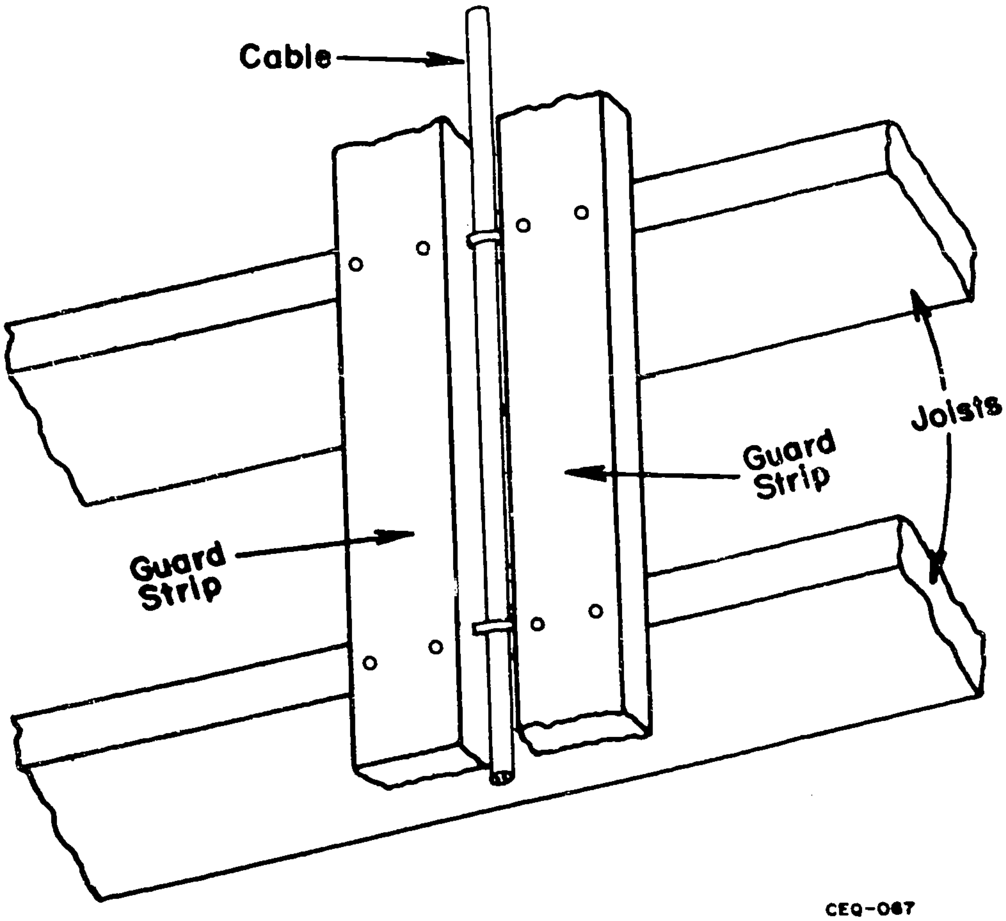


Figure 6–16. Guard stripping nonmetallic cable on attic joists.

NM cable, while the right side of the figure shows cable protected by guard strips.

*Concealed circuits.* Much of the cable put in during circuit installation is referred to as concealed wiring. This description applies to wiring that is installed between the ceilings and floors in multistory buildings, in the ceilings of finished basements, and in the walls of buildings. It is concealed because once the building is finished, the wiring is not visible, nor is it readily accessible.

Concealed cable is installed either through holes bored in wooden framing members or into notches cut in their edges. Holes can be bored with any of the bits discussed earlier. The most commonly used bits are either a ship auger (a bit designed to pull itself through the wood) or a spade bit from 5/8 inch to 3/4 inch in diameter. Bits are powered by an electric drill except in unusual cases. The holes should be drilled in the center of framing members, especially studs. Holes should be drilled in a straight line and at the least possible angle either vertically or horizontally. Holes that are drilled in a crooked line or at much of an angle to the line of pull make it harder to thread the cable through the holes and pull it into position. Also, if the holes are drilled at much of an angle horizontally in studs, the specified 1¼ inches between the hole and the edge of the stud cannot be met. When holes are less than 1¼ inches from the edge of the stud, the cable must be protected from nails or screws. Metal sleeves or plates at least 1/16 inch thick are used for this purpose.

Cable can be put into notches cut in the edge of framing members, as shown in figure 6-21, if the notches will not weaken the building structure. The notches should be as small as possible. Their depth must not exceed one-fifth the width of the wood. Cable placed in notches is protected from nails and screws by 1/16-inch metal plates like those in figure 6-21.

Cable is installed through metal framing members in about the same way as they are wooden ones. Either holes or slots are used and may be cut, punched, or drilled at the factory or in the field. Holes in metal members must have bushings or grommets inserted securely to prevent damage to the cable covering. If holes or slots have been formed so that no metal edge can cut or tear the cable insulation, bushings or grommets are not needed. A steel sleeve, plate, or clip must be installed for protection wherever a cable might be punctured or cut by a nail or screw.

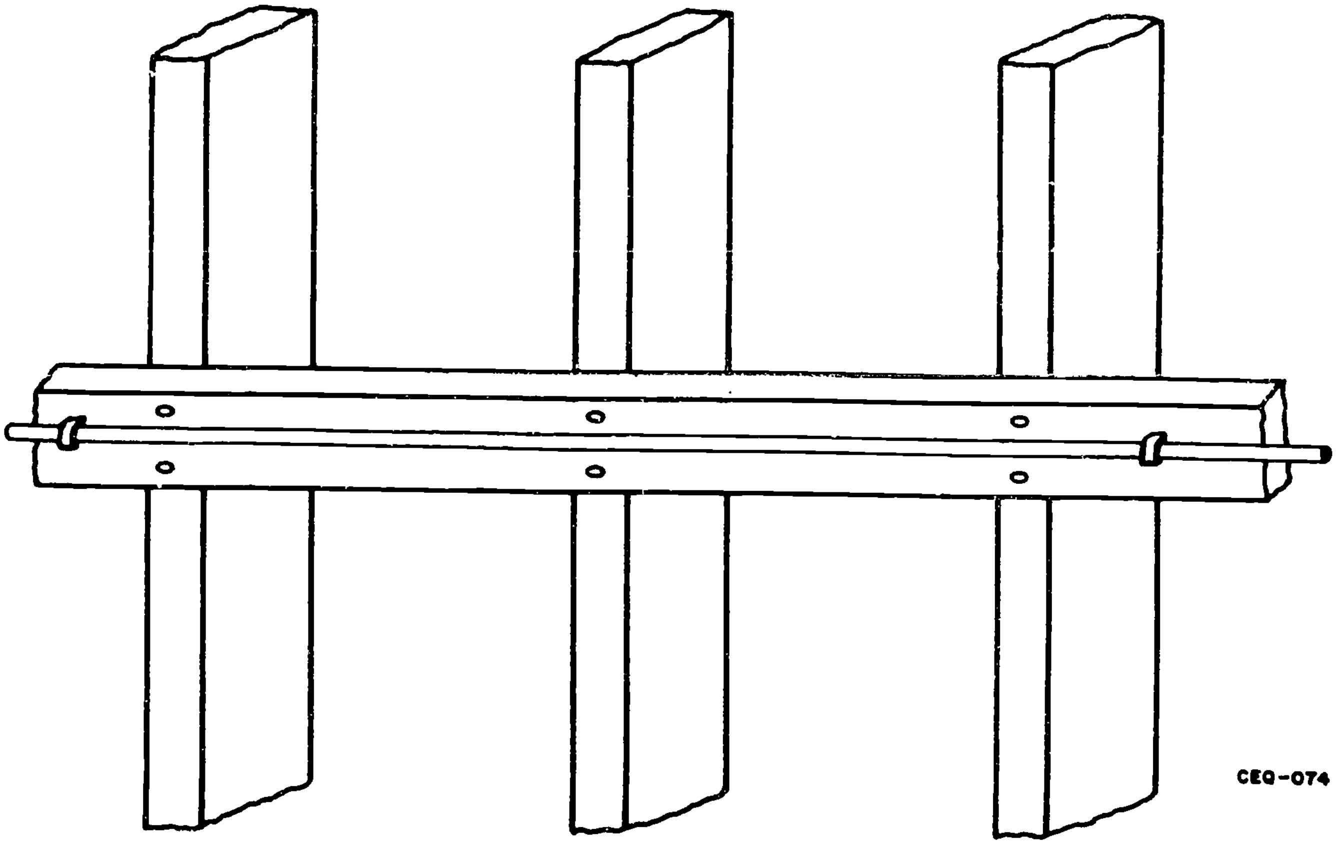

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Figure 6-17. Nonmetallic cable on a running board.

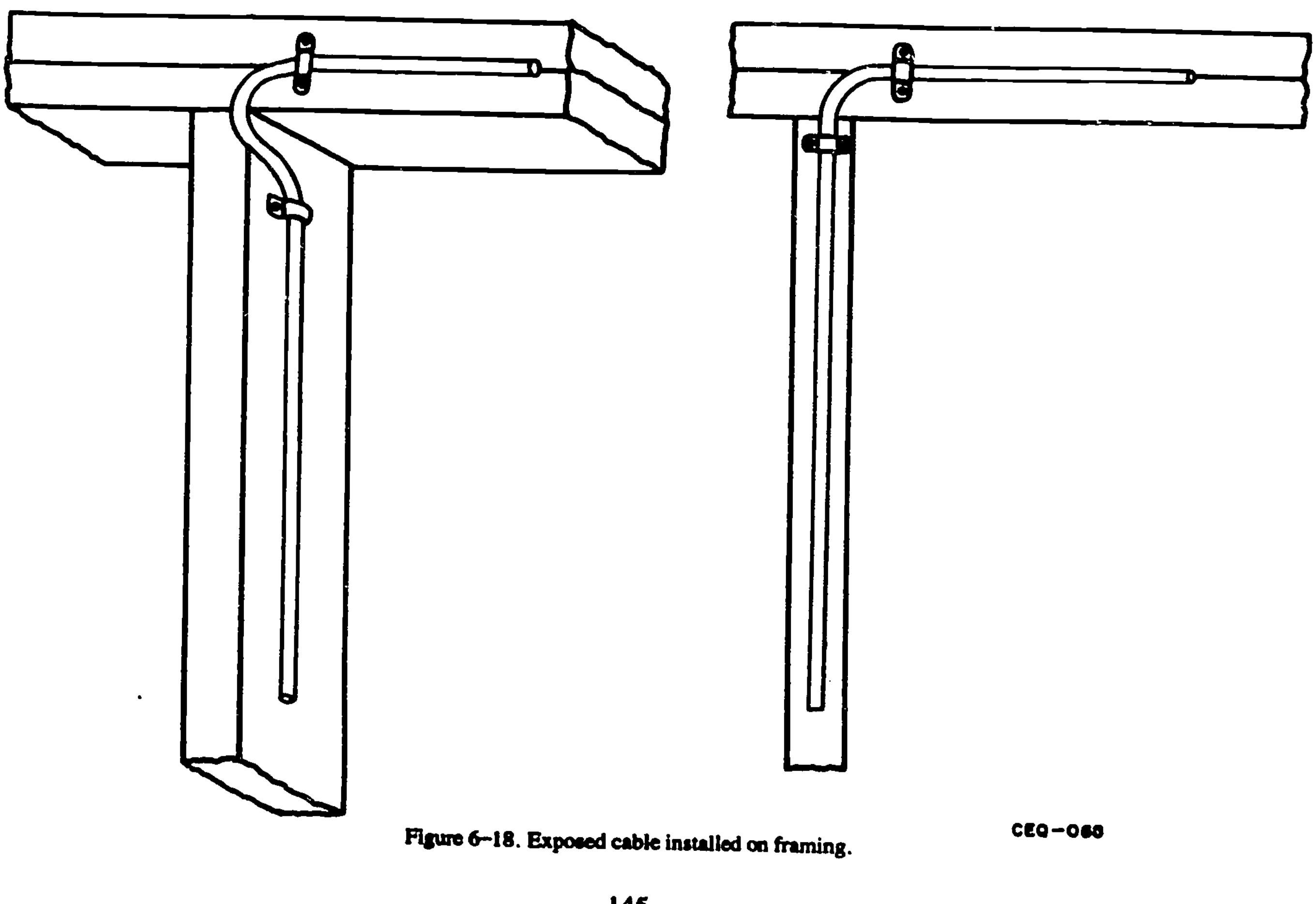

Figure 6-18. Exposed cable installed on framing.

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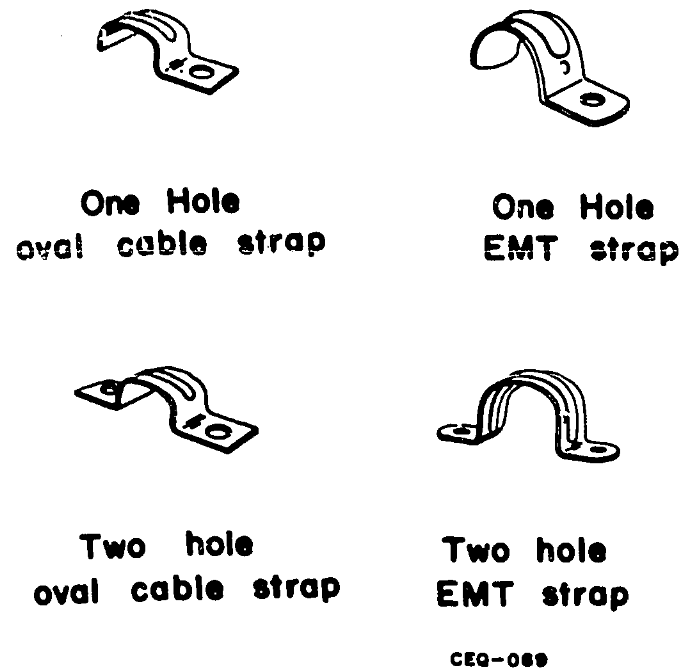



Figure 6–19. Straps for fastening cable.

*Cable installation.* The first step in wiring a building after the distribution panel or panels have been installed is, in most cases, to mark the location of the outlet boxes. The boxes are then mounted in place unless the mounting of a box might interfere with hole boring or cable anchoring. Once the boxes are in place, the needed holes or notches are made for the installation of the cable.

Figure 6-22 shows a general view of how the cable is run during circuit installation. As the figure illustrates, mounting the boxes before you run the cable is not likely to cause a problem with the rest of the work. A careful look at the figure will show that with the boxes installed and the holes bored, the main remaining task to circuit installation is to get the cable from one box to another.

Most cable used for branch circuits is 12/2 with ground and comes in a coil of 250 feet in a carton or box. It may be available in longer lengths from some companies. Larger cable is usually packaged in shorter lengths. The proper length of cable should be removed from the carton at one time to fit the specific run. The best way to do this is to place the carton at one of the outlet boxes and remove enough cable to reach the other box. To remove cable from the carton, grasp the end through the hole in the top of the carton and pull it out. The cable comes out in the form of a spiral. This spiral must be uncoiled before tension is applied to the cable or before it is threaded through any bored holes. Pulling on the coiled cable will cause each coil to become smaller and smaller until it forms a sharp kink that damages the insulation and prevents passage through the bored holes. If more cable must be removed from the carton after the free end is fastened, kinks can be prevented if you turn the box to unwind the coils as the cable comes out.

Install the cable by starting at the free end. Strip 6 inches of the outside covering from the cable end. If the box has cable clamps, remove one of the priouts and insert the stripped cable end through the hole under the clamp until a quarter inch of the cable cover extends beyond the clamp. Tighten the clamp to hold the cable firmly in place. This will give you conductor ends 6 inches long in the box. These ends are needed so that you can make splices or attach devices or fixtures easily. Also, anchor the cable within 12 inches of the box.

Boxes without cable clamps require a little different procedure. After stripping the cable end, remove one of the box knockouts. Then, install a cable connector in the knockout hole. Put the cable end through the connector to expose 1/4 inch of the outer cover and fasten it in place. Nonmetallic single gang boxes without cable clamps may be used. In such cases, the hole is punched out of the box and the stripped cable end is inserted through the hole until a quarter-inch of the outside cable cover is in the box. The cable is then anchored no more than 8 inches from the box.

After the free end of the cable is in the box, work the cable back toward the other box. Run the cable along the framing members, fastening it at points no more than 4½ feet apart. When you get to the other box, cu cable to length, allowing for 6 inches of free conduc' .n the box. Strip the outside covering, insert the cable , fasten it to the box, and anchor it within 12 inches of th. box.

Look again at figure 6-22. As you can see, most of these cables are run through holes in the framing members. When holes are involved, you must plan ahead for easiest installation and the least waste. To run the cable between the two duplex receptacle boxes in the figure, it would be a little easier to put the carton of cable near the box on the right and thread it through the holes to the box on the left. For the circuits that run from the left duplex receptacle box and the switch box to the ceiling outlet, the carton of cable should be placed under the boxes. The cable is then threaded up through the holes to the ceiling outlet. From these examples, you can see that you need to look at what is involved before you start to run the cable for a circuit.

**Exercises (255):**

1. What sources of information does an electrician depend upon when detailed wiring specifications for a building are not furnished?

2. What principle does an electrician use as much as possible when routing circuits?

3. Where will most circuits be in a one-story residence?

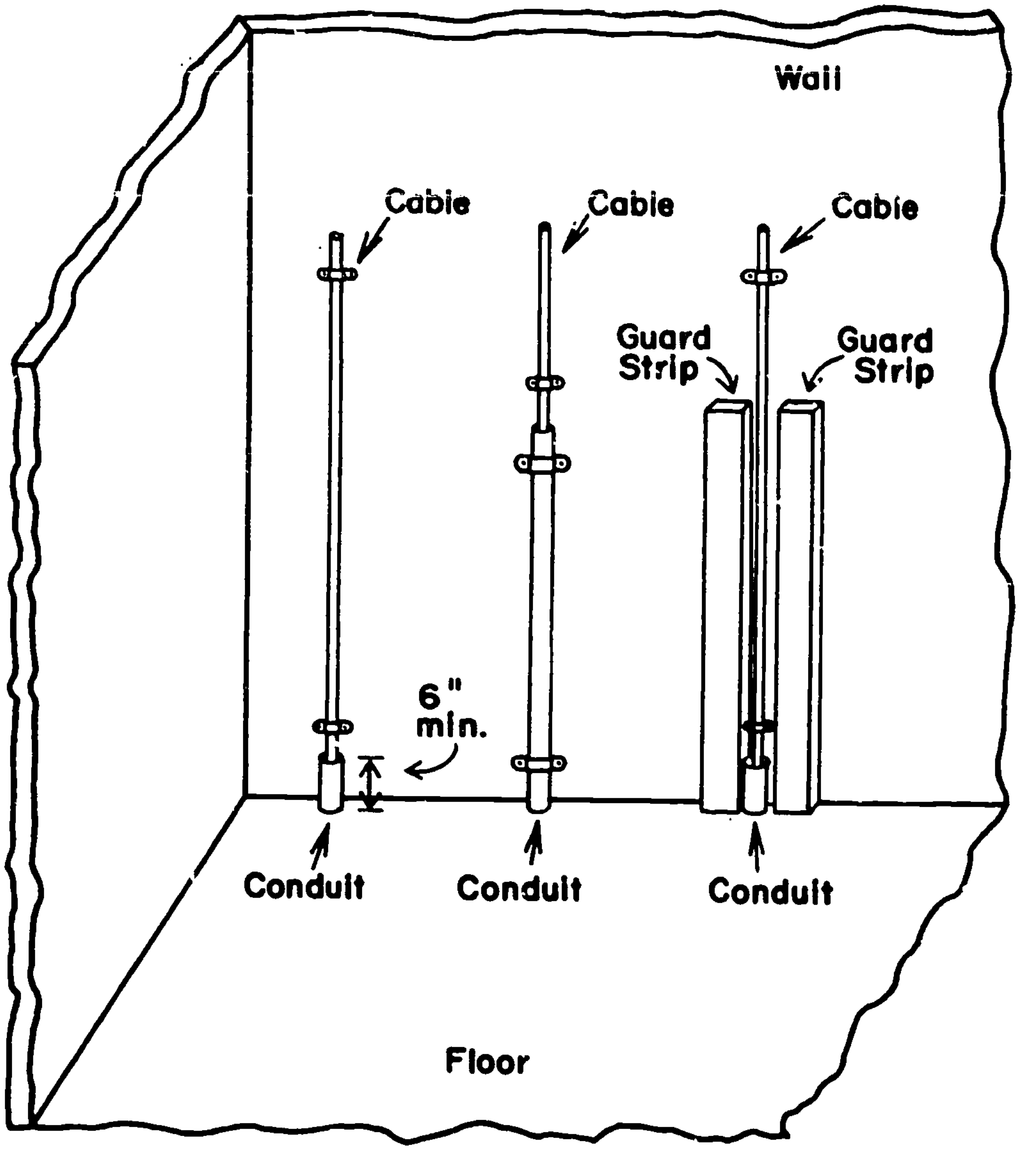



Figure 6-20. Protection of exposed cable.

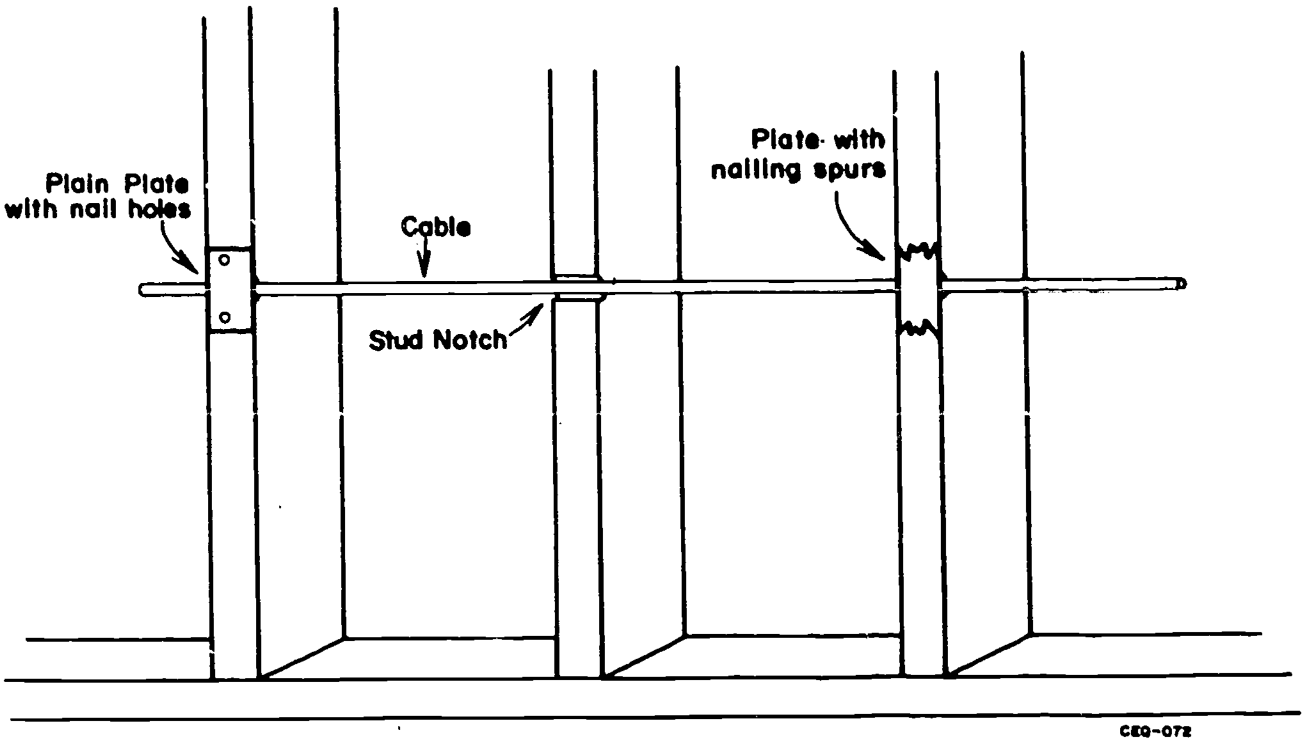



Figure 6–21. Nonmetallic cable installed in notches.

4. Identify the following statements as true or false by entering T or F in the space provided. Correct the false statements.

_____a. Cable must be anchored within 12 inches of a box or cabinet.
_____b. Cable can be anchored at any convenient interval as long as it follows the framing members.
_____c. Concealed cable is usually fastened to framing members with cable clips.
_____d. Cables run diagonally across joists should be fastened on every third joist.
_____e. Cable that parallels a joist is best attached to the side.
_____f. Guard strips must be used for all cable on joists within 7 feet of the scuttle hole.
_____g. All cable mounted on the face of studs and rafters needs guard strips.
_____h. Guard strips are used to protect all cable on top of joists when entry to the attic is by stairs.
_____i. Cable consisting of three No. 8 conductors can be run across the bottom of the ceiling joists in an unfinished basement.
_____j. Cable run at an angle for an overhead light in an unfinished basement must be run through holes in the ceiling joists or attached to a running board.

5. When exposed circuits are put in, how should cable be installed?

6. Where should cable be attached on the stud when it is run to a box mounted flush with the face of an open stud?

7. How is cable installed on a finished surface usually anchored?

8. What is the difference between a cable anchor for a cable with three No. 8 conductors and one for a cable with two No. 12 conductors?

9. When making bends in nonmetallic cable, what must be the size of the radius of the bend?

10. What is the least protection required for exposed cable that passes through a floor?

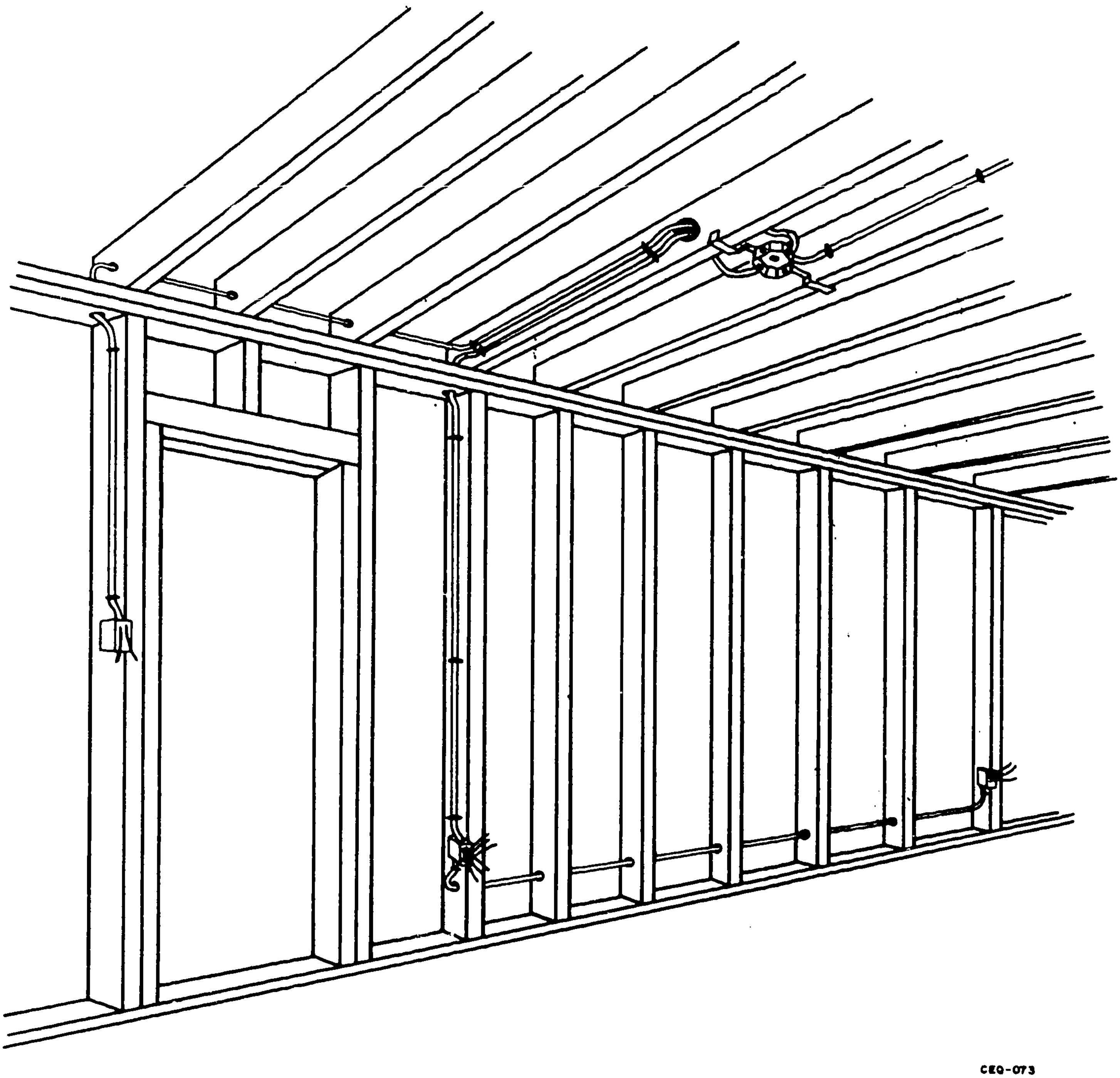



Figure 6–22. Nonmetallic cable installation.

11. What is the least protec... a required for exposed cable that passes through a floor?

12. What action is required where exposed cable on a wall may be vulnerable to physical damage?

13. What is meant by concealed wiring?

14. What does wooden framing require the use of in order to install concealed wiring?

15. What size bit is usually used to install concealed lighting and outlet circuits in a building?

16. Why is it particularly undesirable to drill cable holes in 2" x 4" studs at any angle other than horizontally?

17. How is concealed cable installed when metal studs are used?

18. What actions are taken between the time the distribution panel is installed and the start of cable installation when circuits are being installed?

19. Describe the cable usually used for installing branch circuits and the way in which it is packaged.

20. How is cable removed from its carton?

21. What happens if cable is used without being uncoiled?

22. What is the procedure for installing the free end of the cable in an outlet box?

23. What is the purpose of providing 6 inches of conductor inside an outlet box?

24. How does the procedure for installing cable in a box differ from that previously used when the box does not have cable clamps?

25. How do you install cable in a nonmetallic box that does not have clamps?

26. What is the procedure for getting the cable installed between the outlet boxes?

27. When cutting cable to length for attachment to a box, what must you allow?

28. What should you do before starting to run cable when holes through framing members are involved?

## 6-3. Finish Work

After the circuits have been wired or roughed in, your job comes to a halt for a while. You must wait for the walls and ceilings to be put on. In most cases, you do not start the electrical finish work until the walls and ceilings have been taped, bedded, textured, and painted or papered. After all this is done, you can splice wires as needed and install the receptacle outlets, switches, and lighting fixtures.

**231. Specify types of splices used in interior electrical circuits and identify procedures for making them.**

**Splicing.** A great many of the wires put in for circuits in a building will have to be spliced. These splices are needed to connect wires in various parts of the circuits to form complete circuits that will provide power where it is needed. Splices are also used to connect and add ground wires so that all metal units in electrical circuits are joined together and grounded as a means of reducing shock hazards. The splices you make most of the time are quite simple. The main thing to remember when making a splice is that it must be both mechanically and electrically secure. That is, the splice should be as strong as a continuous wire and must conduct electricity as well as if it were one piece. The splices you make in most cases can be classed as

soldered pigtails, solderless pigtails, tee splices, and compression or crimp joints.

*Insulation removal*. The first step in making a splice is to get the insulation off the conductors so that they can be jointed electrically. On small conductors, No. 10 AWG and smaller, many electricians use a wire stripper like the one discussed in the chapter on tools. When you use a wire stripper, make sure you use the cutting notch that matches the wire size to keep from nicking the wire. A nicked wire will break when it is bent. Cut through the insulation about 1¼ to 1½ inches from the wire's end and then use side pressure to slip the cut insulation off the wire. Insulation can also be removed with a knife. In fact, many electricians prefer this method because of the frequency with which nicks occur when a stripper is used. You must use a knife to take insulation off larger conductors and on the through wire for a tee splice.

When you use a knife, do not ring the insulation or cut straight through it to the wire—in either case, you will probably score or cut the wire. Start by cutting the insulation at an angle of about 30° Remove the insulation as you would sharpen a pencil, taking care not to cut the wire. After the insulation is off, the end of the conductor will look like that shown at the upper left of figure 6-23. Check the ends of the conductors to be sure they are free of insulation and oxidation. Use your blade to scrape the conductors if they are not completely clean.

*Soldered pigtail splice*. The first step in making this splice is to twist the wires together. Cross the wires near the insulation as shown at the upper right of figure 6-23. Leave just enough space to grip the wires with a pair of longnose pliers. Use your sidecutting pliers to twist the wires together until you have six twists, as indicated at the left center of figure 6-23. Fold the ends over against the twists, as shown at the right center. Solder the splice by heating it from the bottom, using a torch or soldering iron, as shown at the bottom of the figure. Heat the wires until they melt the solder, which will flow around the wires to form a good smooth bond. Do not move the splice until the solder has cooled. Many electricians do not bother to bend the wire ends back along the twist, since it is easier to cut them off. Such joints are usually strong enough but are more apt to pierce the tape used for insulation.

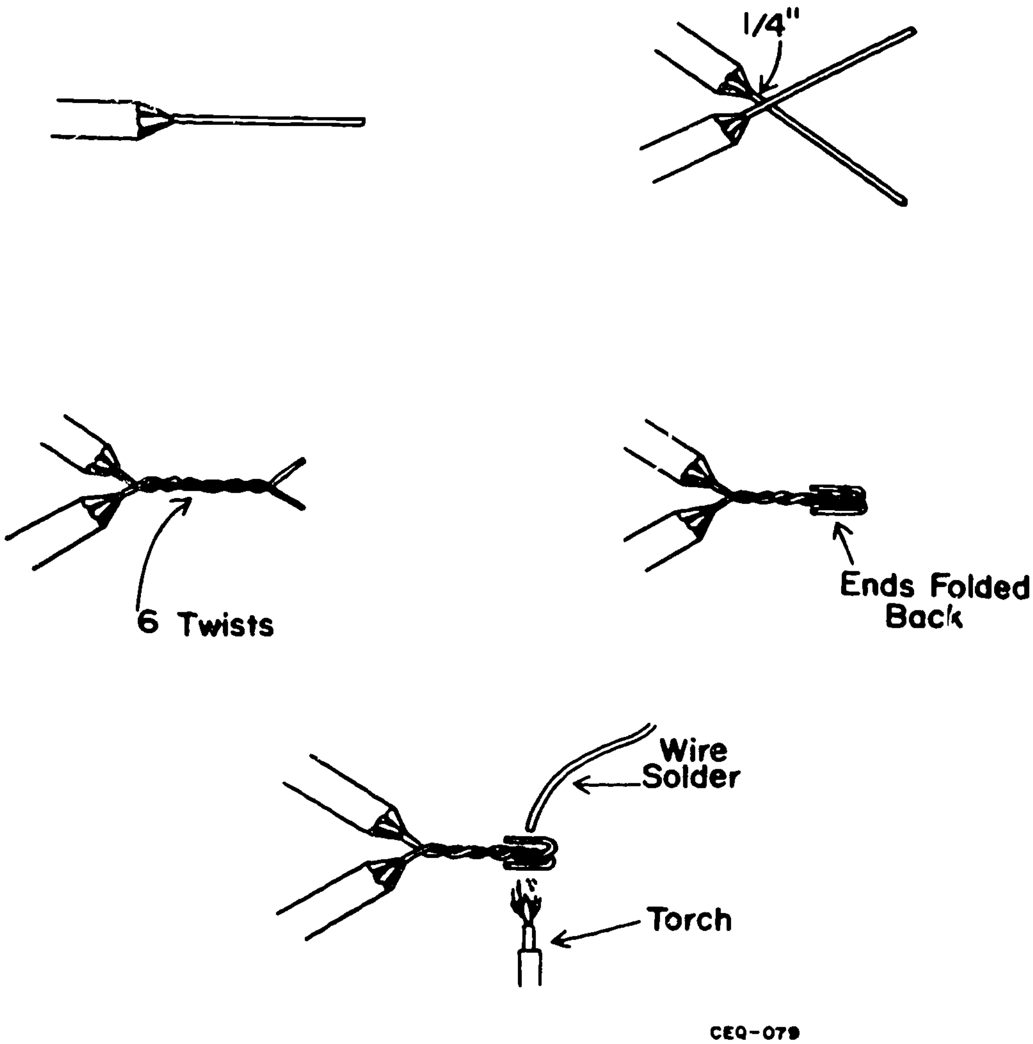



Figure 6–23. Making a pigtail splice.

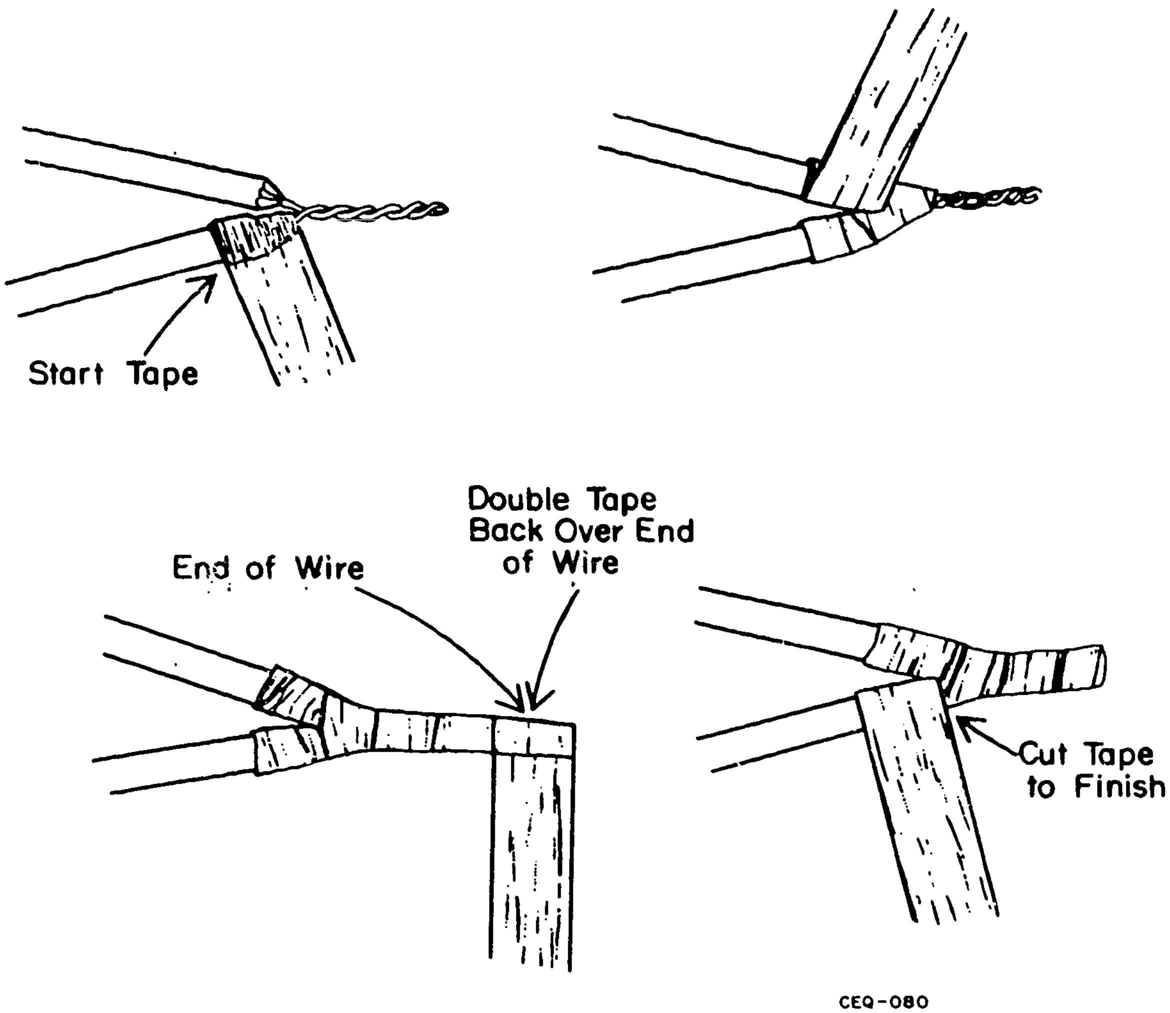



Figure 6–24. Taping a pigtail splice.

Insulate the completed splice with tape. Most insulation is now done with plastic electrical tape. This tape is quite flexible. One layer will insulate against 600 volts. However, most splices are insulated with at least four layers of tape for physical protection. Some tension should be put on the tape as you wrap it so that a close, smooth wrapping is formed. Since the tape stretches, you can vary the tension as needed to make it conform to angle and diameter changes to insure a snug fit. Start the tape on one leg of the Y, as shown at the upper left of figure 6-24. Tape to where the wires join and tape up the other leg, as shown at the upper right of the figure. After two turns, begin taping back toward the end of the splice. Half lap each turn of tape until you are half the width of the tape past the end of the wire as you see in the figure at the lower left. Double the tape back over the end and continue taping, but back toward your starting point. Doubling the tape over also changes the direction of the wrap. Tape back, half lapping each turn, to where you started to tape, as shown at the bottom right of the figure. You should now have a splice insulated with four layers of tape applied in one continuous piece.

*Solderless pigtail splice*. The solderless pigtail splice is quite a bit like a soldered pigtail but is easier to make. The insulation is stripped from the wire ends as before but only about three twists are made in the wires. The splice is then finished with a wire nut. The simplest form of a wire nut is a hard plastic shell with a coiled steel wire insert. Another type of wire nut has a flexible plastic cover over a threaded steel insert. It also has two small flanges to allow you to tighten the nut more than you could a round one.

*Tap splice*. The tap or tee splice gets its name from the way it is tapped or teed off a through conductor. About 1¼ inches of the insulation is cut from the through conductor with a knife (fig. 6-25, upper left). The ends of the insulation are tapered as they would be for a pigtail splice. About 2 inches of insulation are stripped from the end of the tap wire. Place the tap wire over the through wire, as in the upper right illustration, so that there is a quarter- inch space between the insulation and the crosspoint. Make the first wrap of the tap wire as a spread out or open wrap, as shown at the left center of the figure. Now, make two or three tight wraps of the tap wire, then finish with one or two more

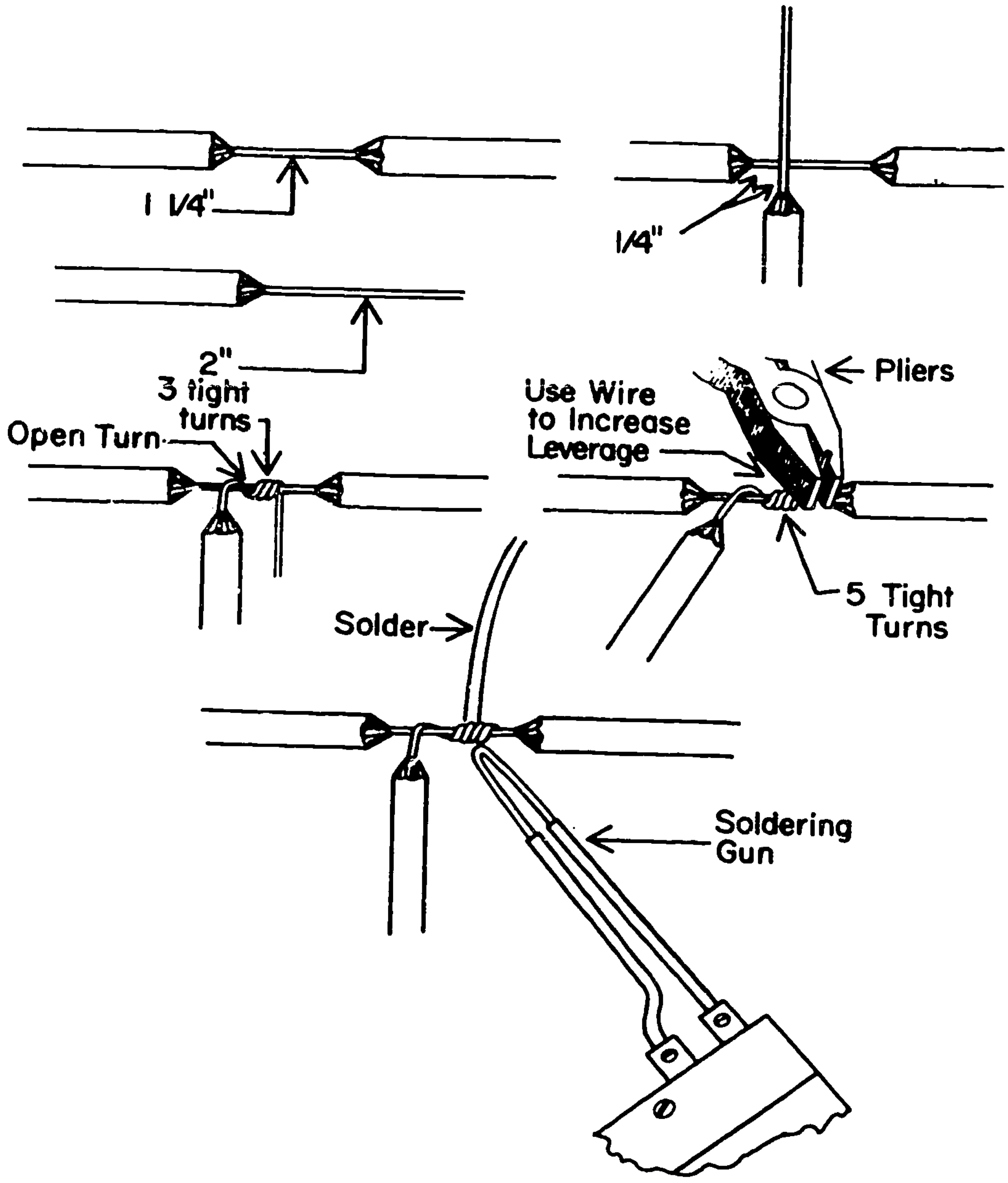



Figure 6–25. Making a tap splice.

wraps that you pull tight with a pair of pliers as shown in the illustration. Cut off the surplus end and squeeze the remaining end down tight. Solder the splice by applying heat under the tight turns until the wire melts the solder and it flows into the joint, as shown at the bottom of the figure. Do not solder the open wrap since it gives some flexibility which will prevent tap wire breakage in case of vibration.

A variation of the tap splice is the knotted tap. Some people like this splice since it locks tightly on the through wire where the tap wire joins to eliminate breaking the solder loose on the joint. The tap wire is looped back around itself after it is hooked over the through wire. The splice is finished with five tight turns around the through wire and then soldered.

The tap splice is insulated with plastic tape in the same manner as is used on a pigtail. You can start the tape at any of the spots where the insulation was cut. Most people find it easier to start at the left end. Begin with two wraps of tape and tape to the other end, half lapping the tape on each turn. At the right end, make four wraps and tape back to the tee. Tape out to the end of the bare tee and back to the through wire. Finish by taping from the tee back to the left end. The result is a splice with four layers of tape put on in one continuous piece.

*Crimp-type splice*. The crimp-type splice (also known as a "compression splice") is made with a sleeve that is crimped in place with a special tool. Crimp-type splicing sleeves come in quite a few different designs, with or

without their own insulation. One that is quite common with interior wiring is a plain noninsulated sleeve used to splice several grounding conductors together, such as would be found in an intermediate receptacle outlet box. To make the splice, all the wires involved are placed through the sleeve and crimped tight with the special tool for that type of sleeve. Make sure each wire is held securely in the sleeve. In this case, no insulation is put on the splice since all the ground wires are bare. A second example of a crimped splice is a pigtail and is similar to those we discussed earlier, except the wires are not twisted together. They are put in the sleeve (actually a closed cap) and crimped with the special tool. This sleeve is already insulated and does not have to be taped after it is crimped.

**Exercises (256):**

1. State two reasons for making splices in an interior electrical system.

2. What two requirements must a splice meet?

3. Name four types of splices used in interior wiring.

4. On small conductors, what is the easiest method of removing the insulation for making a splice?

5. What is the main disadvantage of removing insulation with a stripper?

6. What is used to remove insulation from a No. 8 AWG conductor?

7. How do you remove insulation from the end of a wire with a knife?

8. What action is required if the end of a bare wire is covered with oxidation?

9. Indicate the correct and incorrect statement on making a pigtail splice by entering C or I in the space provided.

   _____a. After the wires are crossed, hold them in position with a pair of sidecutting pliers.
   _____b. A pair of sidecutting pliers are used to twist the wires together.
   _____c. A pigtail splice should have at least three but not more than five twists.
   _____d. Bend the wire ends back along the twists to complete the splice.
   _____e. Solder the splice by heating the wires to melt the solder.

10. What material is normally used to insulate a soldered pigtail splice?

11. How many layers of tape are required for a well-insulated splice?

12. What is the advantage of having a tape that stretches when you insulate a splice?

13. How is tape applied to a splice to insure adequate coverage without going over it several times?

14. How is a solderless pigtail splice made and insulated?

15. The end of a conductor is attached to an unbroken conductor with what type of splice?

16. Identify the true and false statements in the following list by putting a T or F in the blank space:

   _____a. After the insulation is removed for a tap splice, there are three tapered ends.
   _____b. The first wrap of the tap wire is spread out when making a tap splice.
   _____c. The tap wire wraps on a tap splice are all made using a pair of pliers to pull them tight.
   _____d. Solder the full length of wraps to complete a tap splice.
   _____e. When soldering a tap splice, be sure to apply heat to the solder until it flows freely.

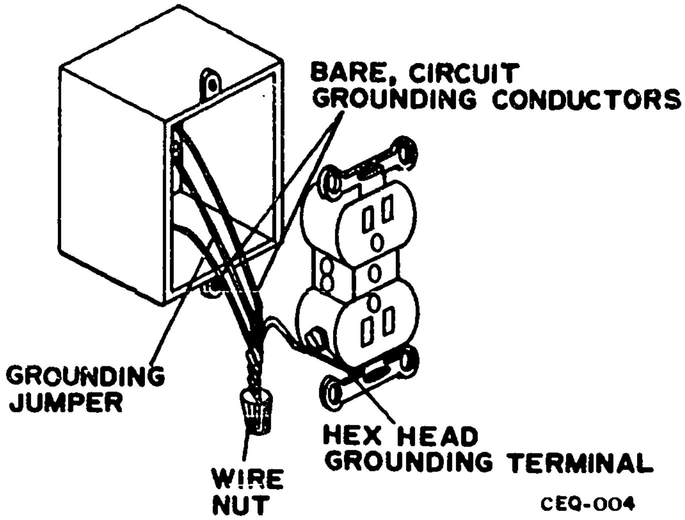



Figure 6–26. Device grounding (more than one receptacle in the circuit).

_____f. A knotted tap splice is less likely to break the solder joint than is a plain tap splice.

_____g. When taping a tap splice, you can start taping at any end of conductor insulation.

17. What two items are needed to make a compression splice?

18. What is the purpose of a noninsulated sleeve?

19. What kind of splice would you make with an insulated sleeve that has one closed end?

**257. Specify accepted practices and procedures to follow when installing equipment grounds at boxes and devices.**

**Equipment Grounding.** Equipment grounding, as explained previously, is the connection of all exposed noncurrent-carrying metal parts of an electrical system to the earth. This is done to protect anyone who might come in contact with these parts from being shocked, should they become hot, and also to protect equipment from damage. Grounding is accomplished when all the noncurrent-carrying metal parts are connected to a grounding conductor (or other means, as approved by the NEC) and the grounding conductor connected to earth at the service equipment or panelboard.

If a circuit is to be wired with nonmetallic sheathed cable, the equipment grounding conductor will be bare, green, or green with yellow stripes. The equipment ground does not normally carry current. The only time it does is when there is a fault in the circuit, such as occurs when a hot conductor touches a box. This fault causes a large current, which trips the circuit breaker or blows the fuse protecting the circuit. Some wiring systems do not need the separate equipment grounding conductor because of the nature of the inclosure used for the wires. These systems include rigid metal conduit, intermediate metal conduit, EMT, and other raceways approved by the NEC. Although the equipment grounding conductor is not required for these systems, there are some places where the system must be bonded to ground. One such place is at the service equipment, as shown in Chapter 4.

*Box grounding*. In the previous section, you learned how to make splices that will insure the continuity of the equipment-grounding conductor throughout the circuit. In addition to the splices required, grounding connections must be made to the boxes used in a circuit to insure that they are also grounded. At all outlet boxes that require grounding according to the NEC, the equipment grounding conductor must be fastened to the box using either a grounding clip or a grounding screw. A screw used for grounding purposes must not be used for any other purpose. When the grounding clip is used, the grounding wire is slipped through the clip and then the clip is forced onto the edge of the box.

*Device grounding*. A device, according to the NEC, is a unit of an electrical system that is intended to carry but not utilize electrical energy. The switches and receptacles you will be installing are devices. The NEC does not require that all devices be grounded. However, the duplex receptacle, a type of device you will be installing quite often, does require that a grounding jumper be connected to the equipment ground. The grounded duplex receptacle comes equipped with a green hexhead screw to be used for connecting the grounding wire. When more than one receptacle is connected in a circuit, the NEC requires that these receptacles be connected to the grounding wire in such a way that the continuity of the circuit-equipment

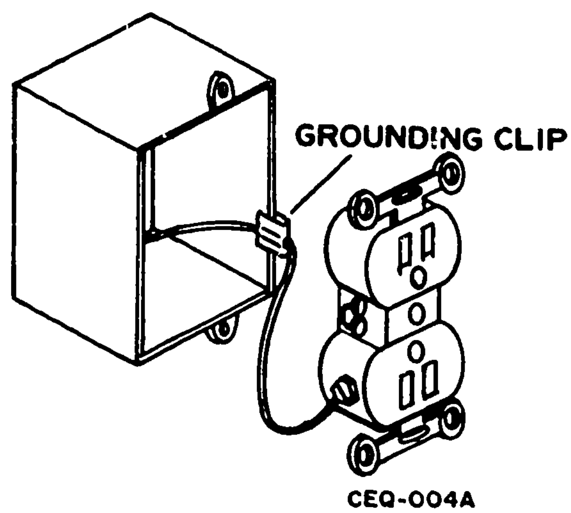



Figure 6–27. Single receptacle grounding using a clip.

ground is not broken if the receptacle is removed. Figure 6-26 shows how the equipment ground must be connected to the receptacle when there is more than one outlet in the circuit. Notice in the figure, that if you were to remove the receptacle, the grounding circuit would still be complete. Figure 6-27 shows an example of how a single receptacle in a circuit can be grounded using a grounding clip. Grounding the receptacle in this way bonds the box, grounding wire, and receptacle, and precludes use of an additional jumper wire. There are two situations that do not require that the receptacle be bonded to the box or to the grounding conductor with a jumper wire. The first is where the box is surface-mounted and there is metal-to-metal contact between the yoke of the receptacle and the box. The second is where the yoke of the receptacle is designed specifically for providing metal-to-metal contact between the yoke of the receptacle and a flush-mounted box.

**Exercises (257):**

1. What type of wiring systems do not require an equipment grounding conductor?

2. On systems that do not require an equipment-grounding conductor, where is one place that the system must be bonded to ground?

3. What are the two methods used for connecting the equipment ground to a box?

4. What grounding requirement must be met when more than one receptacle is connected in a circuit?

5. What two situations do not require using a grounding jumper on a receptacle?

6. On a duplex receptacle, which screw is used for connecting the equipment ground?

7. Under what condition does the equipment ground carry current?

8. How will the equipment ground in nonmetallic sheathed cable be identified?

**258. Specify types of terminal connections used to install switches, receptacles, and fixtures, and cite the practices and procedures used to complete the finish work.**

**Terminal Connections.** The next step of the finish work that must be done before the circuit can be checked for operation is the connection of terminals. Properly made terminal connections are very important for several reasons. The operation of the circuit, prevention of fire, and safety of personnel all depend on good electrical connections. As is true with splices, an electrical connection must be electrically and mechanically secure.

The most common connection used on devices and fixtures is the terminal loop and screw. To make the terminal loop, you must first remove about 3/4 inch of insulation from the end of the conductor that is to be connected. Then use a pair of longnose or needlenose pliers to make a loop in the end of the bare wire. Place the loop around the screw terminal in a clockwise direction and tighten the screw. If the loop is not placed around the screw in this way, the screw will tend to spread the loop as it is tightened. When you make this type of connection, the insulation must cover the wire close to the terminal screw. If too much insulation is removed, the bare wire is exposed and might come in contact with the box or another conductor and cause a ground or short.

Some receptacles and switches are made so that they can be wired from the back without using a terminal loop. With these devices, all you have to do is strip the desired amount of insulation and insert the bare wire into the hole near the terminal screw to complete the connection. With some of these devices, the wire is clamped when it is inserted. With others, you must loosen the screw terminal near the hole, then insert the wire and tighten the terminal screw. The strip gage on the back shows how much insulation should be removed.

The installation of fixtures at an outlet also requires some type of terminal connection. Here again, if the fixture has terminal screws, the most common connection will be the terminal loop. Some fixtures come with stranded terminal wires. If this is the case, the circuit wires are pigtailed to the fixture wires using wire nuts (fig. 6-28).

Remember, when connecting receptacles and fixtures, you must observe the terminal color coding. The ungrounded (hot) wire must be connected to the dark colored (brass) screw of the device or to the black fixture wire. The grounded or neutral (white) wire must be connected to the silver screw of the device or to the white fixture wire. Finally, the grounding wire or equipment ground must be connected as described in the previous objective. The only terminal color coding to observe when connecting switches is when wiring a 3-way or 4-way switch system, the hot wire should be connected to the common terminal of the 3-way switch.

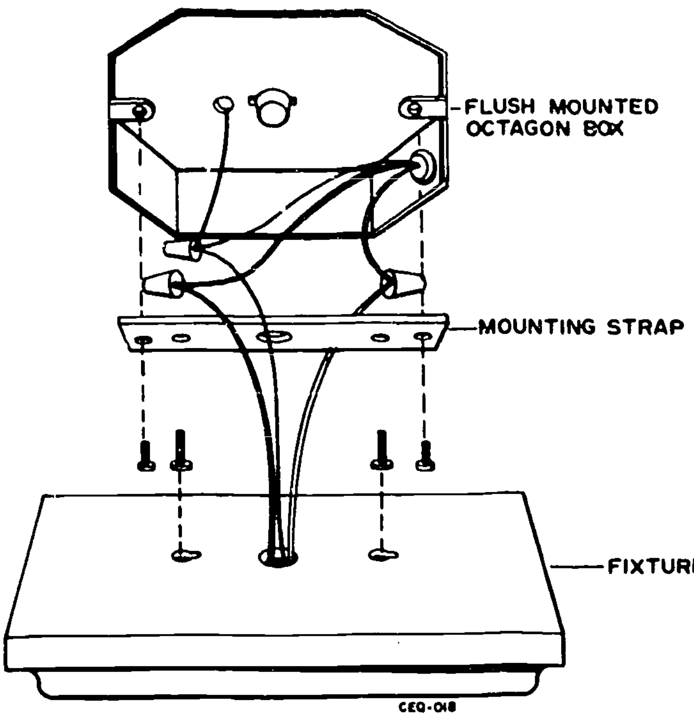



Figure 6-28. Fixture connections.

**Device and Fixture Installation.** Once the splices, terminal connections, and grounding connections are made, the device or fixture can be mounted to the box and the covers can be installed where needed. The mounting of receptacles and switches is the same. To place the device in the box, bend the wires so that they will fold up when the device is pushed into place. Most switches and receptacles come equipped with two 7/8 inch, No. 6 screws, and receptacles come equipped with two 7/8 inch, No. 6 screws with 32 threads per inch (commonly called 6-32 screws) for mounting. The mounting holes on the switch are slotted. These slots let you mount the switch straight up and down, even though the box may not be set straight.

The mounting of fixtures is sometimes a little more complicated, depending upon the type of fixture to be mounted. Those that are mounted directly to the box, such as a porcelain fixture, are attached to the box with 8-32 screws through the mounting tabs. Others that mount to the box may require a mounting strap In this case, you use 8-32 screws to mount the strap to the box and then use the fixture screws to hold the fixture to the strap. Some suspended fixtures are mounted to the box by use of a coupling called a hickey, between the box stud and the fixture stem. The maximum weight of a fixture that can be supported by an outlet box is 50 pounds. Any fixture that weighs more than 50 pounds must be supported in some other way.

Recessed fixtures come in two basic types: prewired and unwired. Both of these are mounted between the joists with special bar hangers. The prewired fixture comes with a separate junction box for the connection of the circuit wires to the fixture wires. This fixture is prewired with flexible conduit and heat-resistant wire. The unwired, recessed fixture must be mounted at least 1 foot from the outlet or junction box from which it receives its power, and must be wired with heat- resistant wire. Flexible conduit must not be less than 4 feet long and no more than 6 feet long.

There are times when you need to mount a fixture directly to the ceiling, especially fluorescent fixtures. To mount a fixture to the ceiling, you should use wood screws, toggle bolts, hollow wall anchors, or lead anchors, depending on the type of ceiling material and the weight of the fixture. On a sheetrock ceiling, wood screws will not hold a fixture unless the fixture mounting holes line up with the ceiling joists. If the holes do line up, you should use wood screws that are long enough to catch a good hold in the wood (at least 1¼ inches long). If the holes do not line up, you should use toggle bolts. To mount an unusually heavy fixture on sheetrock, a wood strip placed between the toggle of the toggle bolt and the sheetrock will keep the toggle from pulling through. Where a fixture is to be mounted on concrete, you should use lead anchors and machine screws. Due to the wide variety of fixtures an methods of installation, consult the NEC for specific installation requirements when fixtures are not familiar to you.

Finally, you are ready to install the covers where they are needed. The purpose of covers for devices and fixtures is threefold. They provide a finished appearance, help protect the conductors and connections, and prevent anyone from coming in contact with hot conductors. There are as many different types of covers as there are types of devices and fixtures. Most of the time, when you are covering a device, you will put on flat switchplates and flat duplex receptacle plates. The switchplate is installed with two 6-32 screws, 3/8 inch long that fasten the plate to the switch. The duplex plate takes just one 6-32 screw to fasten it to the receptacle. Since the plates fasten to the devices, you must make sure the devices are straight so that the plates will be straight. Raised covers are somewhat different in that the device is fastened to the cover with two screws and then the cover is fastened to the box. The device is not actually fastened to the box. If there is any question about installing a fixture cover, refer to the manufacturer's instructions.

**Exercises (258):**

1. What are three reasons for making sure that terminal connections are mechanically and electrically secure?

2. What type of terminal connection is used most often on devices and fixtures?

3. What is the first step performed when making a terminal loop?

4. What tool is used to make a terminal loop?

5. Why must a terminal loop be placed around the screw in a clockwise direction?

6. How are terminal connections made on fixtures that have stranded fixture wires already attached?

7. Which terminal screw is the ungrounded conductor connected to when connecting a receptacle or fixture?

8. Which conductor is connected to the silver terminal of a receptacle or fixture?

9. What size screws are used to mount a receptacle or switch to a box?

10. What is the maximum weight fixture that can be supported from an outlet box?

11. What size screws are used to mount a fixture directly to an outlet box?

12. How far must an unwired recessed fixture be mounted from the outlet or junction box?

13. What type wire must be run to an unwired recessed light fixture?

14. How are recessed fixtures mounted?

15. What are the minimum and maximum lengths of flexible conduit that can be run to a recessed fixture?

16. Name three fastening devices used to mount a fixture directly to a ceiling.

17. When can wood screws be used to fasten a fixture directly to a sheetrock ceiling?

18. How can an unusually heavy fixture be mounted directly to a sheetrock ceiling?

19. What type of fasteners are used to mount a fixture to a concrete ceiling?

20. What are the purposes for covering devices and fixtures?

21. What size and how many screws are needed to attach a flat cover plate to a receptacle?

22. What procedure is necessary to straighten up a crooked switchplate?

# Circuit Installation with Conduit

AS AN ELECTRICIAN in the Air Force, you will be called on to install all types of wiring systems. Unlike electricians in civilian life who often specialize in installing specific systems, you must be able to install any type. In many locations, you may have to install a wiring system that will require the added protection provided by conduit. The types of conduit and fittings and where they are used were taught in Chapter 3. In this chapter, we will discuss the procedures used for cutting, threading, and bending conduit for installation.

## 7-1. Conduit Cutting and Threading

Although it may seem at first glance to be a simple task, cutting and threading conduit efficiently requires considerable skill. With the instruction that follows, and with on-the-job experience, you should soon be able to do this well.

### 259. Specify practices and procedures used for cutting and threading conduit.

**Conduit Cutting.** Regardless of the type of conduit you are installing, you will often have to cut it to make it fit. Rigid conduit can be cut with either a hacksaw or a pipe cutter. Although a vise is not absolutely necessary, it makes cutting with either tool much easier. When you cut any conduit with a hacksaw, you should use a blade with 18 to 32 teeth per inch. A blade with fewer teeth will hang up or bind and may even break. Place the blade in the hacksaw frame so that the teeth will cut when you push the saw forward. Place the pipe in the vise so that there will be ample room between the vise and where the cut will be. This will let you saw without hitting your hands on the vise and will also allow enough room for threading purposes after the cut is made. Remember, let the saw work for you, don't force it. Use a steady, forward cutting stroke with light to medium pressure.

To use a pipe cutter, place the conduit in the vise as was described for cutting with a hacksaw. Put the cutter over the conduit and adjust it until the cutting wheel makes contact at the point of the cut. Tighten the cutter just enough to score the pipe on the first turn, then screw the handle in about one-fourth of a turn for each turn around the conduit until the cut is complete. Cutting oil can be used to ease the cutting action. Intermediate conduit and rigid conduit are cut in the same way.

Thin-wall conduit (EMT) and polyvinyl chloride (PVC) should be cut with a hacksaw, because pipe cutters may flatten the end of the pipe. They also leave a ridge on the inside of the pipe that is very hard to remove. There are tubing cutters made specifically for cutting EMT or PVC, (fig. 7-1), but you must be sure you have the right cutter for the job. As stated before, when you are cutting conduit with a hacksaw or tubing cutter, use of the vise will make the job much easier.

Flexible conduit (flex) and tubing should also be cut with a hacksaw. Because of its spiral construction, flex should be cut at an angle so that only one ribbon is cut all the way through. A slight reverse twist will separate the two ends (fig. 7-2).

Cutting any type of conduit leaves a sharp edge or burr on the inside of the pipe that must be removed by reaming. Reaming can be done with several tools. To ream rigid and intermediate conduit, the reamer shown in figure 7-3 can be used. A rattail file does a good job on any type of conduit. To ream EMT that has been cut with a hacksaw, the handles of a pair of pliers, such as needle nose or sidecutting pliers, will do the job. The important thing is to remove any edge or burrs in the pipe that might cut the insulation when the conductors are pulled into the conduit.

**Threading Conduit.** Once rigid metal conduit or intermediate metal conduit is cut, it must be threaded for use with threaded couplings, locknuts, and bushings. To thread conduit, use a standard conduit-cutting die with a 3/4-inch taper per foot. This die cuts a deeper thread on the end of the conduit and then tapers the cut at the rear or shoulder of the thread. This is just the opposite of a running thread on a bolt. See figure 7-4. You can see both conduits are wrench-tight in the coupling but thread is showing on the outsides. The dies used for threading smaller sizes of conduit are usually hand driven. The handle may be solidly attached to the die, or the die assembly may be of the ratchet type. For larger sizes, or when large installations are made that require considerable conduit threading, a motor-driven, pipe-threading machine is recommended.

The most common rigid conduit threader uses nonadjustable ratchet dies (fig. 7-5), which come in sizes to fit conduit from 1/2 inch to 2 inches. Before threading the pipe, inspect the dies to see that they are sharp and free from nicks and wear. Next, insert the pipe into a vise, place the guide end of the pipe threader on the pipe, and push the threading dies against the pipe with the heel of your hand. With pressure against the threader, take three or four short clockwise strokes downward to start the threads. Continue the threading with clockwise strokes mixed with a reverse stroke every now and then until two or three threads extend beyond the die. To reverse the threader, you must pull the ratchet lock out and turn it a half turn. The reverse turns keep the threads and dies clean and free of bits of metal. Cutting oil applied during the threading helps the cutting process by reducing friction. To remove the threader,

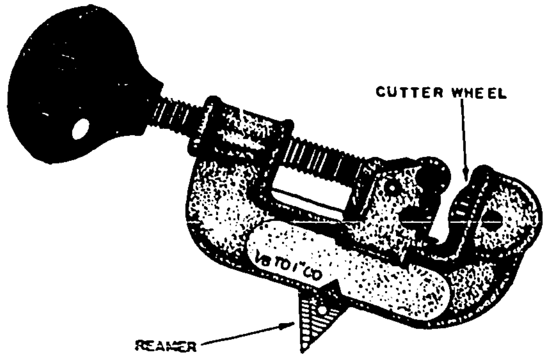



Figure 7–1. Tubing cutter.

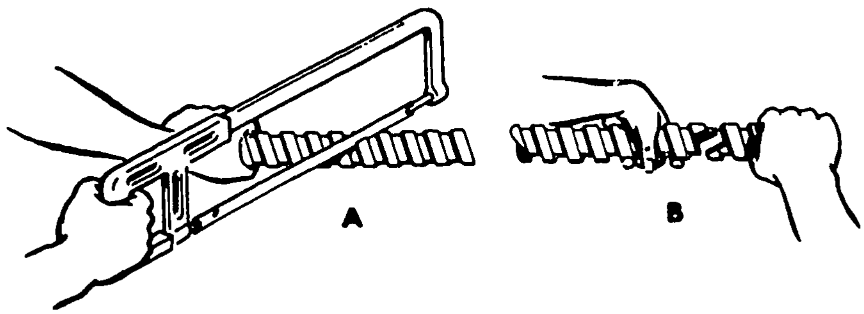



Figure 7–2. Cutting flexible conduit.

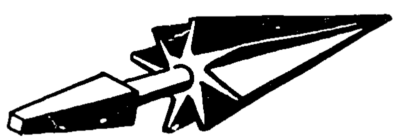



Figure 7–3. Reamer.

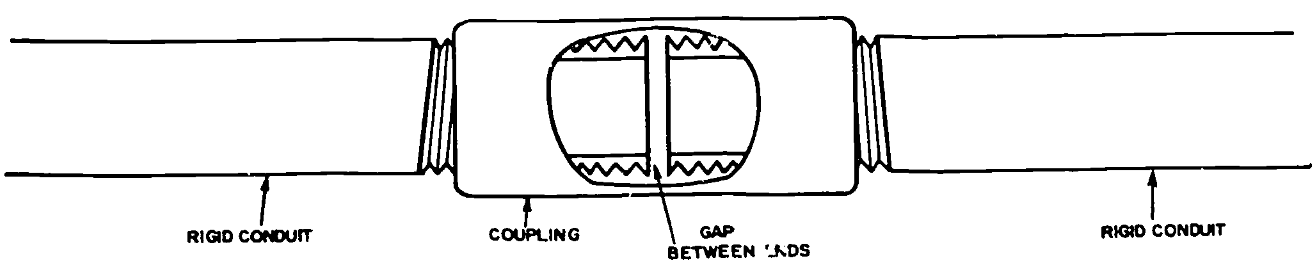



Figure 7–4. Conduit threads in a coupling.

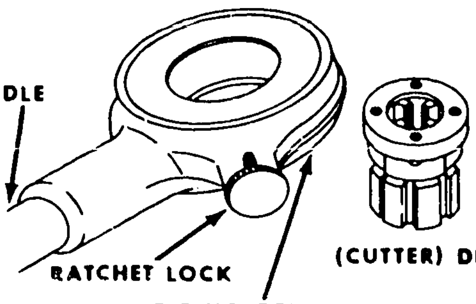




Figure 7-5. Ratchet threader and dies.

release the ratchet lock and turn the die by hand counterclockwise. Removal of the die also cleans the threads.

It is important that the right amount of threads be cut for the job. In other words, a full thread must be cut so that the ends of the conduit will come together in a coupling, as shown in figure 7-4. Full threads are also necessary for the conduit to make a firm seat in the shoulder of a threaded hub of a conduit fitting. If too many threads are cut, the conduit will fit too loosely in the coupling or hub. The procedure described previously for cutting threads until two or three threads extend beyond the die will usually give you a full thread.

Power threaders come in basically two types: stationary threaders built for use in the shop and portable threaders built for use in the field. Both types are driven by electric drive motors that have adjustable chucks and dies for use on different size conduits. Portable threaders will normally handle up to 2-inch conduit. Shop threaders may be built to handle up to 6-inch conduit. The manufacturer's operating instructions should be consulted before using these power tools.

**Exercises (259):**

1. How many teeth per inch should a hacksaw blade have for cutting intermediate or thin wall conduit?

2. How should you place the blade in a hacksaw frame for normal use?

3. How much space do you leave between the cut and the vise when using a hacksaw?

4. How tight should the pipe cutter be on the first turn when cutting intermediate conduit?

5. Why should a hacksaw be used instead of a pipe cutter for cutting EMT or PVC?

6. What is the procedure used for cutting flexible conduit or tubing?

7. What procedure must follow the cutting of any conduit, and how is it done?

8. What two types of conduit must be threaded for use with threaded couplings, locknuts, and bushings?

9. What type of cutting die must be used to thread conduit?

10. During the threading procedure, what is the purpose of the reverse strokes?

11. Describe the procedure used to obtain a full thread.

12. What size conduit will portable threaders normally accommodate?

13. How are power threaders driven?

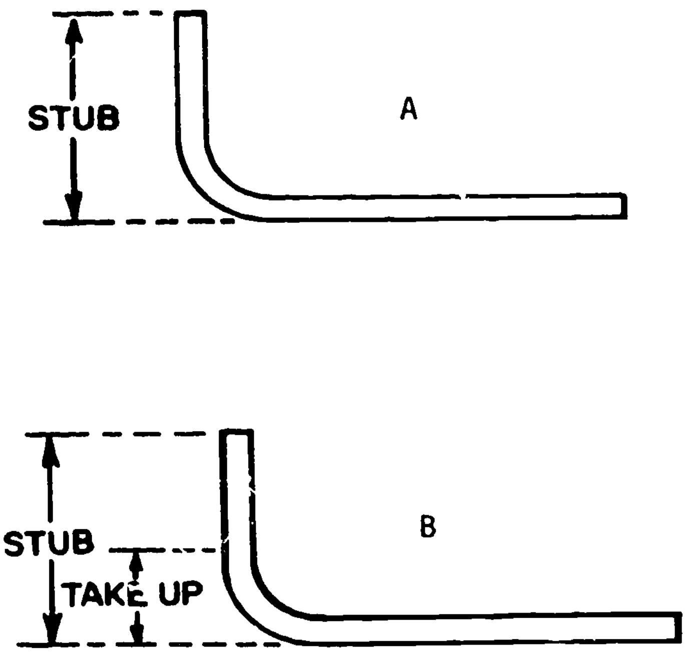



Figure 7–6. Conduit takeup and stub.

## 7-2. Conduit Bending

One of the tasks you will have as an electrician is to make field bends in conduit. Although conduit bending is thought by many electricians to be quite difficult, it is really fairly simple. It does require some thought, simple math calculations, and a lot of practice. But, it is like swimming—once you have learned how, you never forget.

**260. Differentiate between types of conduit benders, and cite procedures required to make various field bends in conduit.**

When you are installing conduit, you will need to make bends to go over or around obstacles. These bends must be made without reducing the inside diameter of the conduit at the bend. You will make most bends on the job as a part of the installation procedure. These are called field bends. Factory-made bends may be used instead of field bends; however, they increase the cost of the job because they require more cutting, threading, and bending.

Since most of the bending you do will be done with manual benders, the bending procedures taught in this section will be made with those types of tools. There are basically two types of manual benders used for bending rigid metal conduit and EMT. They are rigid benders, called the hickey and the one-shot bender. The one-shot bender is normally made for EMT, but some are made to be used for both EMT and rigid. The one-shot bender is so called because a full 90° bend can be made with a single motion. Conduit sizes up to 1-inch rigid or 1¼-inch EMT can be bent without much trouble using manual benders. Larger sizes are usually bent with power benders.

**Types of Bends.** Conduit installations are normally referred to as runs of conduit. A run of conduit is the conduit, fittings, straps, conductors, and bends needed from one opening to the next; for example, from the panelboard to the first outlet or from the first outlet to the second outlet. In a run of conduit, or from the first outlet to the second outlet, there cannot be more than the equivalent of four 90° bends, for a total of 360°. This includes the bends located at the box or opening. The purpose of allowing only so many bends in a run of conduit is to help in pulling conductors into the conduit. It has been learned from experience that if more than 360° of bends are used, it is very difficult to pull conductors through the bends. By using a conduit body in a run, you provide an opening for pulling the conductors without having to mount a box. At the same time, you can make a turn around or go over an obstacle and maintain a neat conduit installation.

*Right-angle bend.* One of the most common bends you will make in the field is the right-angle bend, more commonly called a quarter bend, a 90° bend, or just a 90. It can be used for going around an inside corner, into the top or bottom of a box from a horizontal run, or for just going over an object.

Anyone can make a 90° bend in a stick of conduit and then cut it off to make it fit the situation, but this practice wastes time and material. The secret is to find out where the bend is needed, mark the conduit accordingly, and make the bend in the right place. This practice will save time and material. Before you can determine where to place your bender on the pipe, there are some things you must know. First, the distance from the end of the conduit to the back of the 90° bend is called the stub length or simply the stub (see fig. 7-6,A). Second, the radius of the bend takes up a part of the stub. This part of the stub is called takeup, and is shown in figure 7-6,B. The amount of takeup depends on the type and size of the conduit you are bending. (See table 7-1).

Now let's see how a 90° bend is made to fit a specific situation. Suppose the conduit is to be run from the top of a panel to the ceiling and then run horizontally along the ceiling. The conduit is to be 1/2-inch EMT and a one-shot bender is to be used. The first step will be to measure from the top of the panel to the ceiling. This will give you the stub length. Assume this length is 18 inches. Measure 18 inches from the end of the conduit and make a mark at this point, as shown in figure 7-7. Next, look at table 7-1 to find the takeup inches back toward the end of the conduit from your first mark and make a second mark like you see in figure 7-7. Now, place the conduit on the floor and straddle it so that the stub is in front of you. Hold the bender in one hand with the lip on the floor pointed toward the stub end. Use the other hand to place the conduit in the bender. Align the bender arrow with the takeup mark, as shown in figure 7-7. Put one foot on the footrest and hold the handle with both hands. To make the bend, apply pressure on the footrest as you pull on the handle until the handle is at about a 30° angle with the floor, as shown in figure 7-8. You should now have a 90° bend with an 18-inch stub. To check and see whether the bend will fit properly, you can place it next to anything that you know is a right angle and measure from the floor to the end of the stub. If the bend is not a full 90, you can place the bender back on the conduit as

TABLE 7–1

CONDUIT TAKEUP

**Amount of Take Up For 90° Bends (One-shot Benders)**

| Size and Type of Conduit | Take Up |
|---|---|
| 1/2" EMT | 5" |
| 3/4" EMT or 1/2" Rigid* | 6" |
| 1" EMT or 3/4" Rigid* | 8" |
| 1 1/4" EMT or 1" Rigid* | 11" |
| *IMC and Rigid will be the same | |

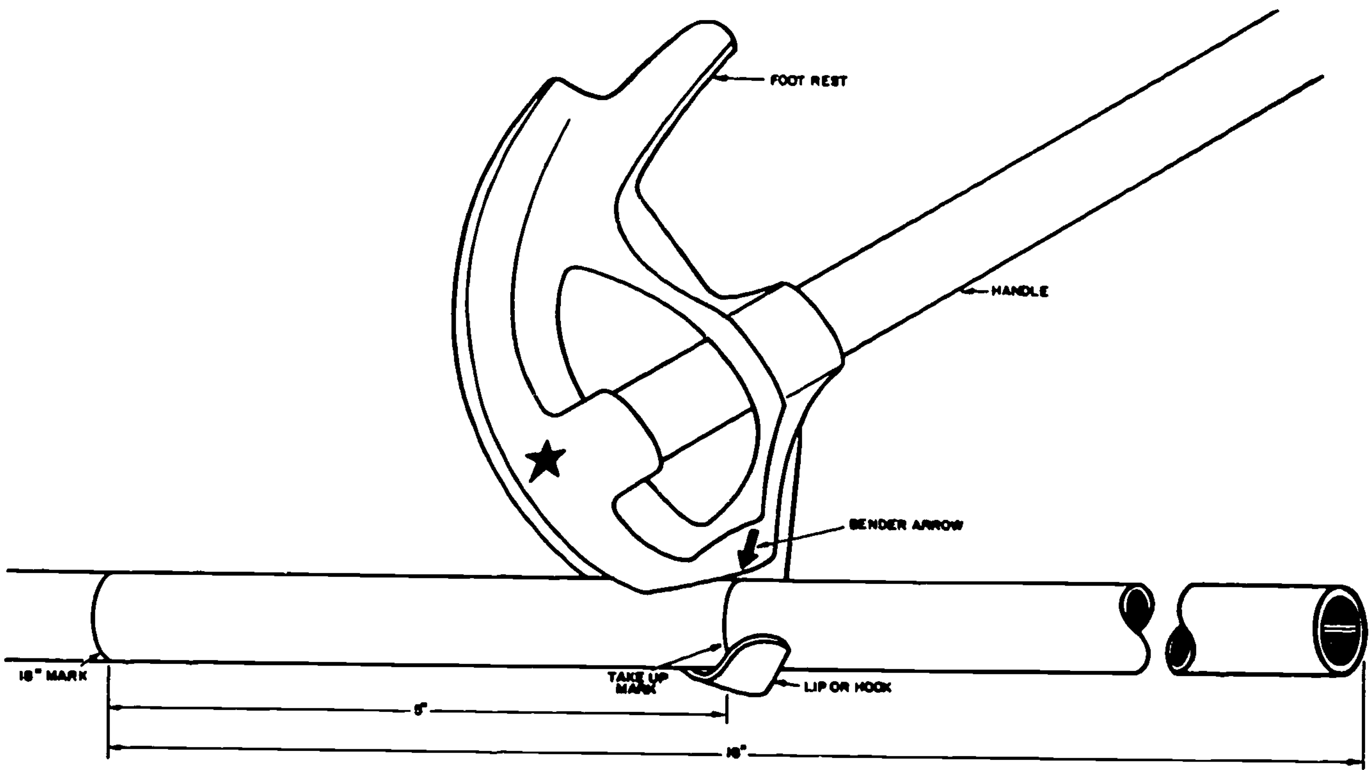



Figure 7–7. Alignment of arrow and takeup mark for bending 90°.

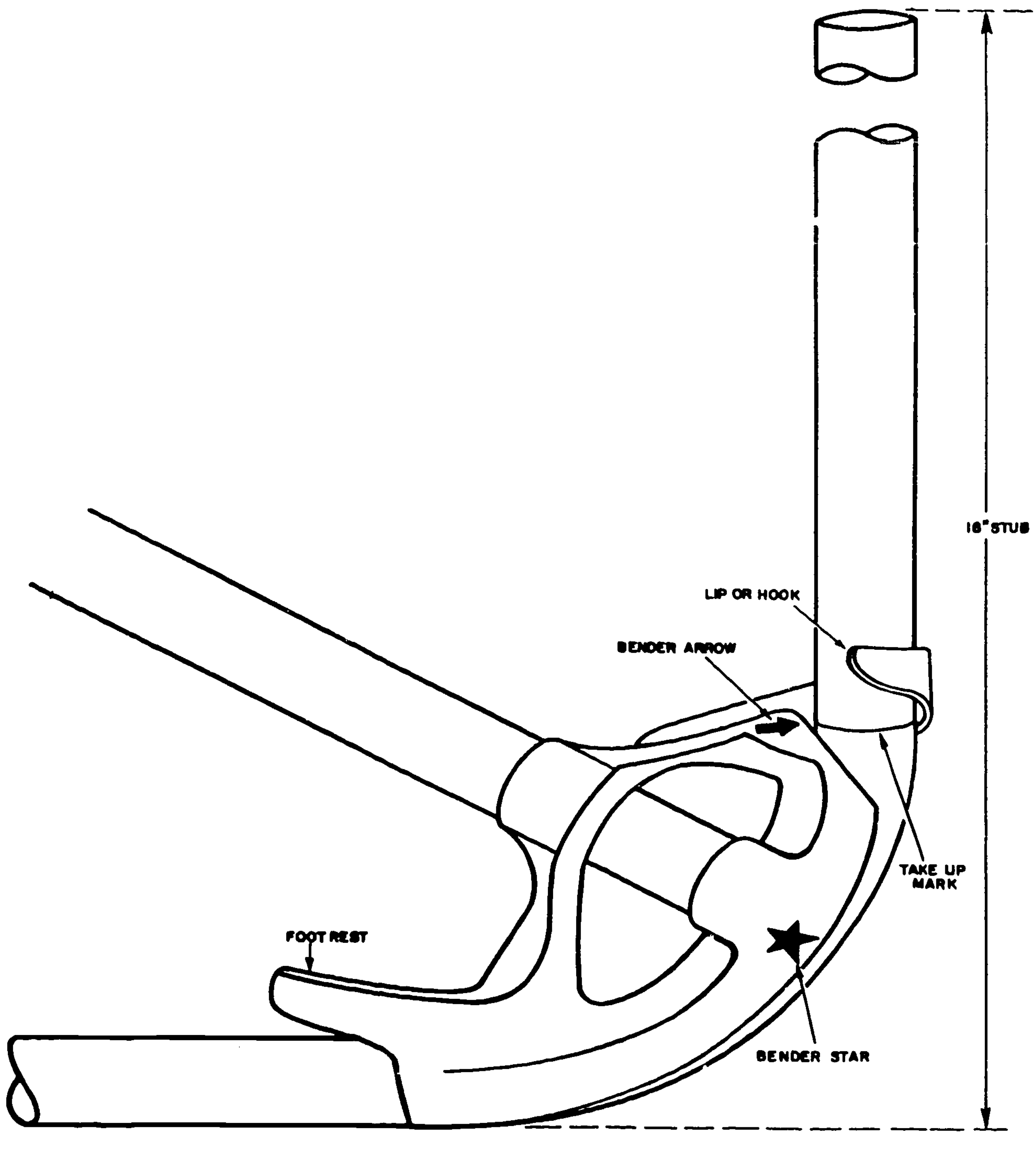



Figure 7-8. Right-angle bend. (90°).

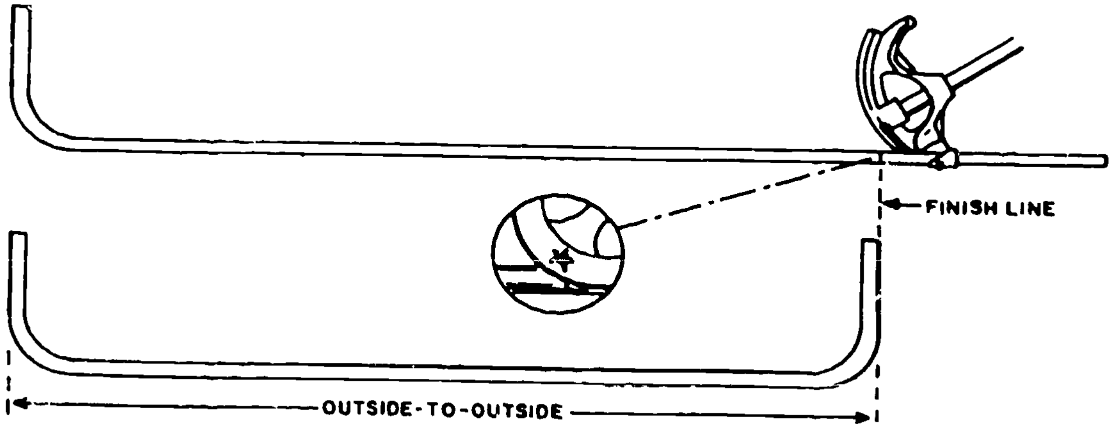



Figure 7–9. Using the star for back-to-back bend.

described before and pull more bend. If it is more than a 90, you can place the handle of the bender over the end of the stub and with one foot on the conduit on the floor, spring the stub back. (Right-angle bends should always be made with the conduit and the bender on the floor.)

*Back-to-back bend.* The back-to-back bend is actually two adjacent 90° bends made in the same piece of conduit. You make the first 90° bend with a certain amount of stub, as described previously. To determine where to place the bender for the second bend, you must first have an outside-to-outside measurement. This measurement is the distance from the back of the first bend to where you want the back of the second bend. You must then transfer this measurement to the conduit and make a mark.

There are two methods to make the second bend. The first is to subtract the takeup, use the arrow on the bender, and pull the bend in the same direction as you did the first bend. The second method, and probably the easiest, is to turn the bender around, line up the star on the bender with your outside-to-outside measurement, and pull the bend in the opposite direction, as shown in figure 7-9.

*Offset bend.* An offset bend is two equal bends in opposite directions. It is used to avoid contacting a part of the structure or to bring the conduit out from the structure to match a knockout in a box or panel. Figure 7-10 shows an offset into a utility box. The angle of the bends in an offset depends on several things—how much offset is needed, how much room there is where the offset is going to be placed, and the type of obstacle you are avoiding. The offset shown is usually about 1 inch in depth and the bends are about 10° angles. There is no way to mark the conduit for a box offset of this depth. The amount of bend and the distance between them are estimated. The key to making a good box offset is practice. Notice that after the bends are made, the conduit sections on each end of the offset are parallel to each other.

To make accurate offsets of 2 inches or more in depth, a predetermined distance can be marked on the conduit. The distance between the bends depends on the depth of the offset and the amount of bend that you are going to use. Table 7-2 shows the formula you should use to find the distance to be marked on the conduit. It also shows the constant multiplier that must be used in the formula for the angle of bends you intend to use.

Let's use an example to see how the formula works. Suppose you need to avoid a part of a structure that requires a 3-inch offset and you are going to use 30° bends. Table 7-2 shows that the constant multiplier for 30-inch bends is two. Using the formula, multiply the depth of the offset (3 in), times the constant multiplier (2 in), and the result is the distance needed between the bends (6 in). You place the marks for the bends 6 inches apart; and using the arrow of the bender, make a 30° bend on the same side of each mark, as shown in figure 7-11. In this example, a 30° bend gives us the offset we need. If you make both bends inside the marks, you will end up with much less than the desired offset. If you make both bends outside the marks, you will have too much offset. The amount of bend, in this case 30° at each mark, is obtained by using the degree markings on the bender, as shown in figure 7-12. Notice that the side of

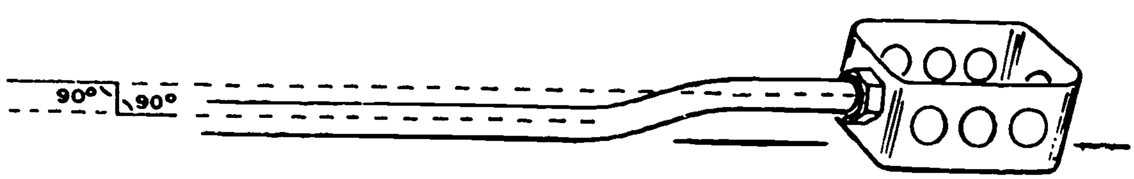



Figure 7–10. Box offset.

TABLE 7–2

OFFSET BENDING FORMULA

**Formula and Constant Multiplier For Determining Distance Between Bends When Bending Offsets**

| **Formula** OFFSET DEPTH x CONSTANT MULTIPLIER = DISTANCE BETWEEN BENDS | |
|---|---|
| **Angle of Bends** | **Constant Multiplier** |
| $22\frac{1}{2}^{\circ} \times 22\frac{1}{2}^{\circ}$ | 2.5 |
| $30^{\circ} \times 30^{\circ}$ | 2.0 |
| $45^{\circ} \times 45^{\circ}$ | 1.5 |
| $60^{\circ} \times 60^{\circ}$ | 1.2 |

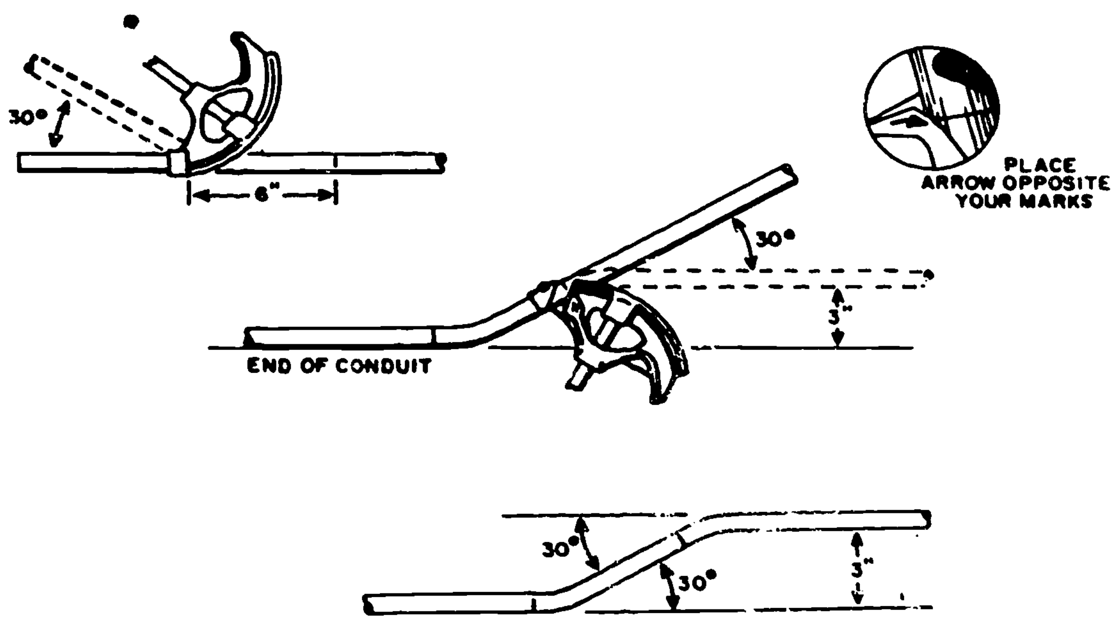



Figure 7–11. Bending an offset.

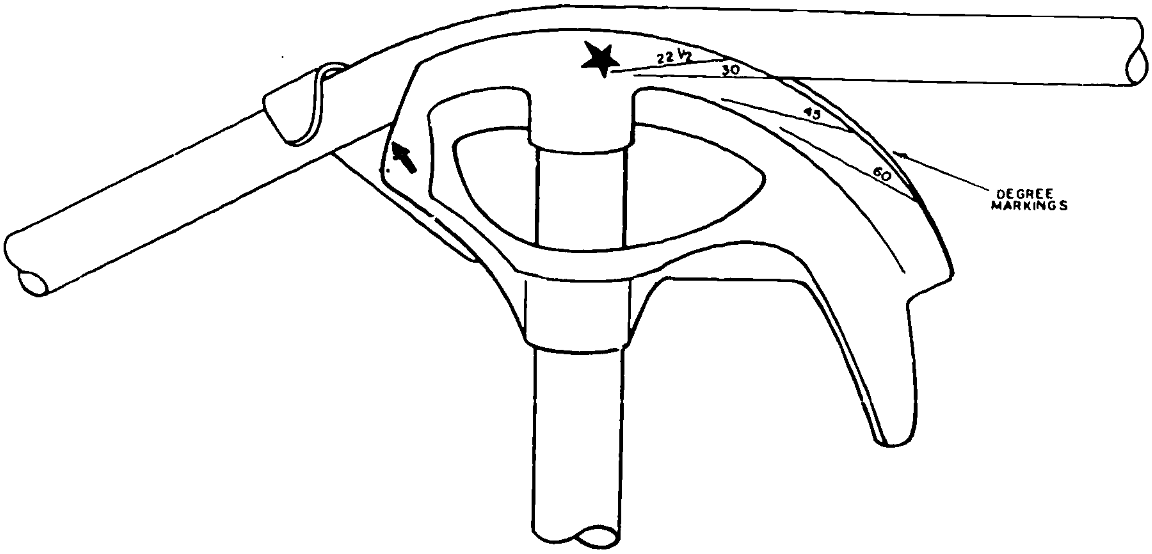



Figure 7–12. Bender degree markings.

the conduit closest to the bender is in line with the 30° marking on the bender. If you have a bender without markings, you can make a layout of a 30° angle on a large piece of paper or on the floor with chalk. Then check the bend against the 30° angle of the layout Normally, offsets are made by making the first bend on the floor and the second bend in the air.

The procedures for making the different types of bends discussed thus far have all been with a one-shot bender. The same bends can be made with a hickey bender, although the procedures are slightly different. For instance, to make a 90° bend in 1/2-inch rigid metal conduit, the steps shown in figure 7-13 must be used. Let's say you need a 20-inch stub at the end of the 1/2-inch stick of rigid. The steps for bending with a hickey are as follows:

*a*. Mark off 20 inches from the end of the conduit.

*b*. Determine the takeup for 1/2 inch rigid (see table 7-1).

*c*. Make a second mark 6 inches back toward the end of the conduit.

*d*. Place the hickey at the second mark and pull about a 30° bend.

*e*. Move the bender toward the 20-inch mark about 2 inches. Pull another 30° bend.

*f*. Move the bender to where the heel of the bender is on the 20-inch mark and complete the 90° bend.

Since the hickey bender does not usually have degree markings on it, you must estimate the amount of bend you are making with each bite. Small bites reduce the possibility of crimping or kinking the conduit.

Bending conduit is an art. Like all forms of art, the more often it is done correctly, the better the artist becomes.

**Power Benders.** Power benders are used for bending larger sizes of EMT, IMC, and rigid conduit. They are also used where many bends must be made, regardless of the size conduit being used. They come in many types and sizes. Some of the more common ones are the hydraulic one-shot, sweep, thin-wall and the mechanical thin-wall, and sweep benders. The hydraulic benders use either a hand pump or an electric pump to move a shoe that does the actual bending. Figure 7-14 shows a hydraulic sweep bender that uses a hand pump. By using different size bending dies at different locations on the tie bar, this bender can be used to bend several types and sizes of conduit. The procedures for making the different types of bends with power benders are very similar to those used with manual benders. The main difference is that with the power benders, takeup for 90° bends and the distance between

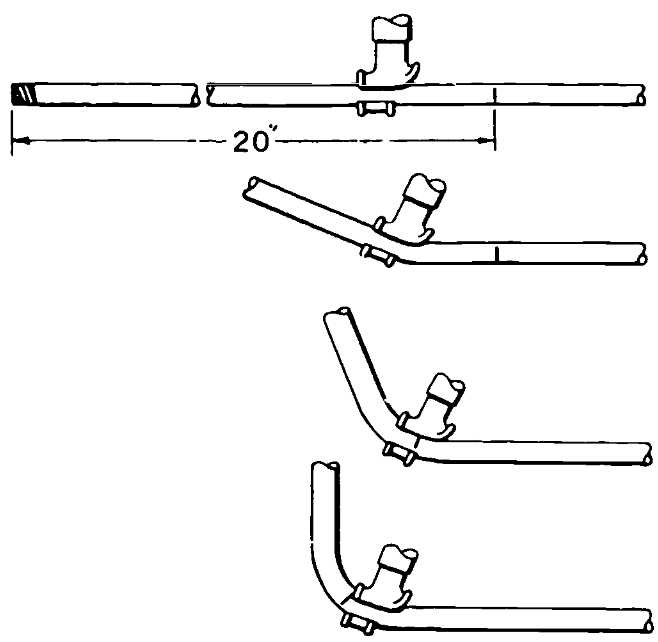
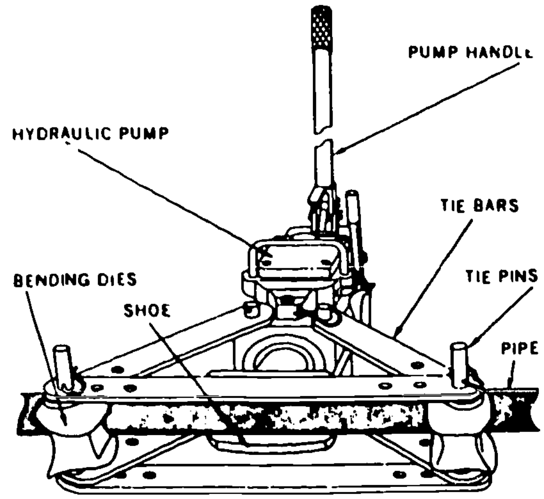



Figure 7–13. Bending a 90 with a hickey.




**Hydraulic Bender**

Figure 7-14. Hydraulic bender.

bends for offsets will not be the same as those shown in tables 7-1 and 7-2. This is due mainly to the fact that you are dealing with larger sizes of conduit or the shoes of the bender give a different radius of bend. Because there are so many different types and manufacturers of benders, be sure and check the manufacturer's instructions before doing any bending.

**Exercises (260):**

1. What are bends made during the installation procedures called?

2. How should bends in conduit be r de?

3. What are the two most common manual benders called?

4. Which manual bender is used to make a full 90° bend with one motion?

5. How many degrees of bends can be ma le in a run of conduit?

6. What makes up a run of conduit?

7. What is the distance from the back of a 90° bend to the end of the conduit that was pulled up called?

8. What is the part of a stub that is the radius of a 90° bend called?

9. To make a 90° bend with a 10-inch stub using a one-shot bender and 1/2-inch EMT, what is the takeup and how should the bender be placed to make the bend?

10. How is a 90° checked?

11. What is a back-to-back bend?

12. Describe the procedures used to make the second 90° of a back-to-back bend.

13. Describe a box offset.

14. The distance between the bends of an offset depends on what two things?

15. What formula is used to find the distance between bends for an offset?

16. Describe the procedures for bending an offset once the distance between the bends is determined and marks are placed on the conduit.

17. How is the amount of bend for an offset checked if the bender does not have degre markings?

18. What are the procedures for making a 90° bend with a hickey?

19. What do hydraulic benders use to move a shoe that does the actual bending?

20. What is the main difference in procedures for bending with power benders versus bending with manual benders?

## 7-3. Conduit and Conductor Installation

In previous sections, we have discussed types of conduit and the fittings used with these types. We have also discussed cutting, threading, and bending conduit. Now, we will cover the specific requirements for installing each type of conduit and how conductors are pulled into them.

**261. Cite practices and requirements you should follow in installing conduit.**

**General Requirements.** Several general requirements apply to all types of conduit installation. All raceways must be installed as a complete system before any conductors are pulled into them. In other words, the run of conduit as described previously including conduit, fittings, and supports must be complete before the conductors are installed. A run of conduit should be as straight and direct as possible. When a number of conduit runs are to be installed parallel and next to each other, you should install them all at the same time. The minimum size raceway that can be installed is generally 1/2-inch electrical trade size. Specific exceptions to this rule include EMT, rigid, and flexible conduit installed in specific locations.. The exceptions for each type are outlined in the NEC. All types of conduit must be reamed after they have been cut. Conduit threaded in in the field must be threaded with a die that has a 3/4 inch taper per foot. Where conduit enters a box or fitting, a bushing must be used to protect the conductor insulation from being cut or torn. Also, never use threaded couplings with running threads.

Running threads weaken the conduit and may come loose. Threaded couplings and connectors used with any type of conduit must be made with tight connections. When the couplings or connectors are to be buried in concrete or masonry, they must be the concrete-tight type; or when installed in wet locations, they must be the rain-tight type.

**Supports.** Conduit must be supported by straps or hangers throughout the entire run. On a wooden surface, nails or wood screws can be used to secure the straps. On brick or concrete surfaces, you must first make a hole with a star or carbide drill and then install an expansion anchor. Use an expansion tool to force the anchors apart, forming a wedge to hold the anchor in the hole. Then secure the strap to the surface with machine screws attached to the anchor. On tile or other hollow material, secure the straps with toggle bolts. If the installation is made on metal surfaces, you can drill holes to secure straps or hangers with machine or sheet-metal screws.

The number of supports needed depends on the type conduit being used. Holes or notches in framing members may serve as supports. EMT and IMC require supports within 3 feet of each outlet box, junction box, cabinet, or fitting, and every 10 feet thereafter. Rigid metal conduit must also be supported within 3 feet of a box, but the distance between supports may be increased to 20 feet on direct vertical runs of rigid from machine tools and other equipment if threaded couplings are used and the riser is supported at each end.

Rigid nonmetallic conduit must be supported as follows:

| *Conduit Size (Inches)* | *Maximum Space Between Supports (Feet)* |
|---|---|
| 1/2–1 | 3 |
| 1 1/4–2 | 5 |
| 2 1/2–3 | 6 |
| 3 1/2–5 | 7 |
| 6 | 8 |

In addition, it must be supported within 3 feet of each opening.

Flexible metal conduit and liquid-tight flex must be supported at intervals not to exceed 4½ feet and within 12 inches on each side of every outlet box or fitting. Exceptions to this are runs of 3 feet or less where flexibility is needed, or 6 feet when connecting light fixtures.

**Conduit Bodies.** When you run conduit from one point to another, you often need to make more turns than the NEC allows in a single run (360° of bends). When this is the case, you can use a fitting called a conduit body. Conduit bodies are often referred to by their brand name, such as condulet or unilet. A conduit body, as defined in the NEC, is "a separate portion of a conduit or tubing system that provides access through a removable cover to the interior of the system at a junction of two or more sections of the system or at a terminal point of the system." Figure 7-15 shows some of the more common conduit bodies. Figure 7-16 shows how a conduit body is put in conduit between two outlets to keep the bends within NEC limits for a single run. As you can see, the run on the left has bends that total 360°, which is all the NEC permits. Thus, a conduit body had to be installed so that the conduit could be continued to the box on the right. After all conduit has been installed, supported, and connected to the boxes, you are ready to install the wire.

**Exercises (261):**

1. What general requirement must be met before conductors can be pulled into any conduit?

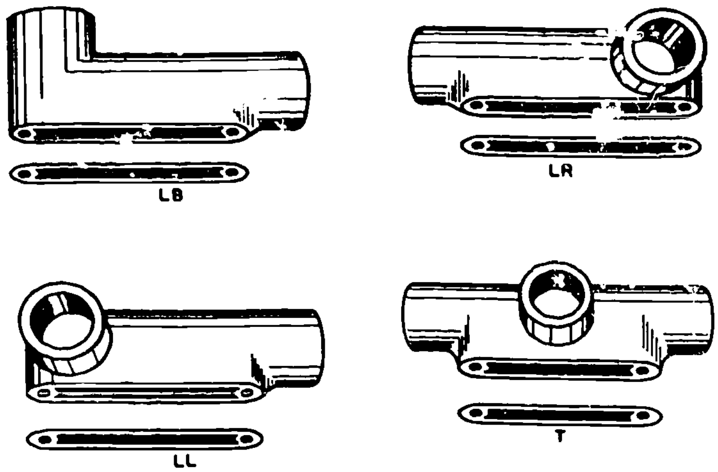



Figure 7–15. Conduit bodies.

2. How should a run of conduit be installed?

3. When a number of runs are to be installed next to and parallel with one another, what procedures must be followed?

4. Generally, what is the minimum size conduit that may be installed?

5. What must be done to any type conduit after it is cut?

6. A die used for threading conduit must meet what requirement?

7. Where conduit enters a box or fitting, what device must be used to protect the conductor insulation?

8. Are running threads allowed to help in the installation of conduit? Why?

9. How is conduit supported on wooden surfaces? Concrete surfaces?

10. With the exception of flexible conduit, conduit must be supported within how many feet of each outlet box, junction box, cabinet, or fitting?

11. Flexible conduit must be supported at intervals not to exceed how many feet and within how many inches on each side of every outlet box or fitting?

12. How does a conduit body increase the total number of bends you can put between two outlets?

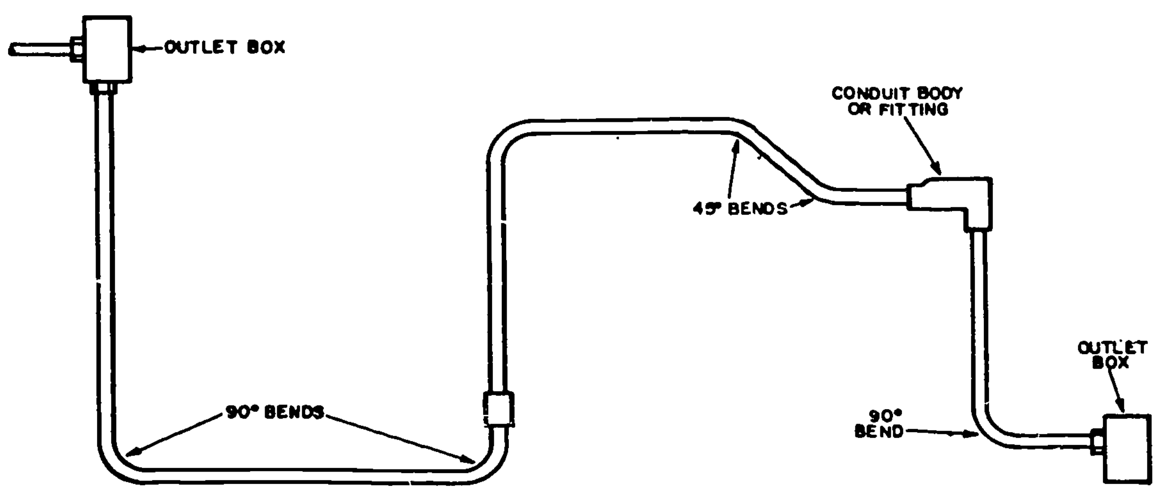



Figure 7–16. Conduit body installed.

**262. State the procedures used to install conductors in conduit.**

**Conductor Installation.** While nearly all types of wire may be used in conduit installations, the most common type used is TW. This letter designation simply means that the wire or conductor has thermoplastic, moisture-resistant insulation. To determine the length of wire to be pulled, simply add: (1) the lengths of conduit, (2) the size and number of boxes to go into or through, (3) the length of wire to leave in the boxes, and (4) the makeup at the distribution panel.

For short conduit runs with only two wires, the conductors can be pushed through the conduit from one box to the next. When the conduit has several bends and more than two con ductors will be installed, a fish tape must be used to pull the wires through the conduit. The fish tape normally has a hook on one end that is pushed through the conduit. The hook also makes it easier to push the tape through. If the hook is broken off, you can make a new one with a pair of pliers and a propane torch. The torch is used to heat the end of the tape to take out the temper. On a 1/8-inch tape, heat about 3 inches of the end of the tape until it is red hot and bend in a hook about an inch long, as shown in figure 7-17. This shape of hook seems to work best. After the hook is formed, reheat the end of the tape until it is red. Allow the end to cool until it becomes straw colored. Then, plunge it into a can of water until it is cool. This process restores the temper to the hook area.

Once you have the fish tape in the conduit, attach the hook to the wires to be pulled, as shown in figure 7-17. Remove 4 to 6 inches of the insulation from the ends of the wires and thread the ends through the hook in opposite directions; bend them back and twist them around each other. Tape the hook and bare conductors to strengthen the attachment and make pulling easier. Use just enough tape to cover the hook and wires.

Wire pulling usually takes two people—one to pull the fish tape, the other to feed the conductors into the conduit. The fish tape should be fed into the end of conduit from which it will be easiest to pull. It is usually best to pull the conductors from the distribution panel to the first box in the run, especially if the panel is energized. This prevents your having to pull on the steel tape near an energized bus. Whenever conductors are being pulled into energized panels, be careful to keep clear of the bus bars. All energized parts should be covered with a rubber blanket.

When several conductors must be fed into a conduit, you should keep them parallel, straight, and free from kinks and bends. Wires that are allowed to cross each other form a bulge and are hard to pull around bends. Whenever possible, feed conductors downward; e.g. from the second floor to the first, so that the weight of the wires will help in the pulling process. Another way to ease the pulling of conductors is to rub an approved lubricant, such as soap, talc, soapstone, or other noncorrosive substance, onto the insulation or blow it into the conduit. You may find that it is hard to keep the fish tape from slipping in your hands when pulling long runs or runs with several bends. When this is a problem, the back side (insulation crushing point) of a pair of side-cutting pliers may be used to grip the tape to give you a good pulling handle.

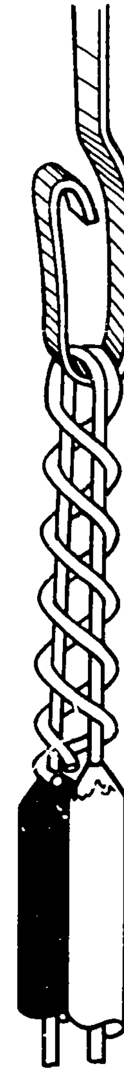


Figure 7-17. Wires attached to fish-tape hook.

Remember, at least 6 inches of free conductor must be left at each outlet and switchbox to make up splices or to connect devices. Conductors that are not spliced or connected to a device can be pulled directly through the box.

The number of conductors you can have in conduit is based on the size of the conduit, the type of conductor insulation, and the size of the conductors. The NEC, Chapter 9, has several tables to help you determine how many conductors of a certain size and insulation type you can have in a given size of conduit. These tables are based on fill. That is, the cross-sectional area of the conductors inside the conduit can take up only a certain percentage of the free space inside the conduit. You must use these tables whenever there is a question on the number of conductors to be pulled. Too many conductors in a conduit causes overheating, which reduces conductor ampacity. (See fig. 5-12).

Once you have installed the conductors and all other finish work is complete, you are ready to do the electrical finish work. Finish work for conduit installations is the same as that for NM cable installations, which was covered in Chapter 6 of this volume.

**Exercises (262):**

1. What four factors are used to determine the length of conductor to be pulled for a circuit?

2. What device is used to pull conductors in a run of conduit?

3. What equipment is necessary to make a hook on the end of a fish tape?

4. How is the temper restored to a fish tape after a hook has been formed?

5. Describe the procedure for attaching conductors to a fish tape.

6. When installing conductors in a run between an energized panel and the first box, the pulling should be done from which location?

7. Describe the procedures for feeding conductors into conduit.

8. What type of lubricant can be used to aid in conductor installation?

9. What tool can be used as a handle to help pull a fish tape?

## 7-4. Circuit Extensions

Building designers and electrical planners try to anticipate the future electrical needs of the occupant prior to construction of a building. Most of the time the electrical systems are more than adequate. Changes in the use of the building, new equipment, or a change of walls may call for additions to existing circuits. These additions are called circuit extensions.

**263. Identify types of circuit extensions in terms of their uses and design features, and distinguish between correct and incorrect practices to follow in installing them.**

A circuit extension, as the name implies, is used to extend an existing circuit. It can be a nonmetallic extension, an underplaster extension, surface raceway, or a multioutlet assembly.

**Nonmetallic Extensions.** A nonmetallic surface extension is an assembly of two insulated conductors within a nonmetallic jacket. It can be used only as an exposed run, in a dry location, from an existing 15- or 20-amp branch circuit. The grounding contact of a receptacle used with this extension must be connected to a grounded cold water pipe near the equipment. Nonmetallic surface extensions can be installed only in a building that is used as a residence or office. It cannot be installed in unfinished basements, attics, or roof spaces; and the voltage between conductors cannot exceed 150 volts.

These additional requirements also apply:

*a.* The extension must be a continuous unbroken length of the assembly with no splices or exposed conductors between fittings.

*b.* Each run must terminate in a fitting that covers the end of the assembly.

*c.* One or more extensions can be run in any direction from an existing outlet, but not on the floor or within 2 inches of the floor.

*d.* NM surface extensions must be secured or supported at intervals not exceeding 8 inches.

Another type of nonmetallic extension used is nonmetallic sheathed cable, which was discussed in a previous chapter. The only difference between installing it as a branch circuit and as an extension is that it may be fished between access points in concealed work. When you do fish it between these points, it does not have to be supported.

**Underplaster Extensions.** An underplaster extension is used to extend an existing branch circuit in a building of fire-resistive construction. It can be run in standard sizes of rigid conduit, flexible conduit, IMC, or EMT. You can also use armored cable or mineral-insulated, metal-sheathed cable. The method of installation depends on the material you use. For those extensions installed in any of the conduit types, the requirements are the same as those covered previously in this chapter for each type of conduit. To install extensions using either of the types of cables, consult the NEC articles on AC cable and MI cable for requirements. An underplaster extension is installed on the face of masonry or other material, connected to the existing

circuit, and then buried in the plaster finish of the wall or ceiling.

**Surface Raceways.** Where an extension is to be run on the surface of a wall or ceiling and appearance is important, surface raceway is used. It is used because, after it is installed, it can be painted to match the surroundings.

Surface raceways come in two types—metal and nonmetallic. Both form a channel for holding wires and come in two parts, which can be separated. The back is mounted on the wall or ceiling, and the front is snapped to it. Use flathead screws on the inside through mounting holes to mount surface raceway or a supporting clip.

Surface raceways are designed so that the sections and all accessories can be coupled together mechanically without damage to the wires. They come in various sizes with factory made fittings, such as pull boxes, junction boxes, switchboxes, elbows, couplings, bushings, straps, and adapters. Generally, surface raceways can be used only in dry locations. They cannot be used where they will be concealed, subject to severe physical damage, or where there is 300 volts or more between conductors. The number of conductors that may be installed will be based on fill, just as it is with any raceway. The manufacturer of the raceway usually provides a table for determining how many conductors can be installed in each size.

**Multioutlet Assemblies.** A multioutlet assembly, as defined in the NEC, is a type of surface or flush raceway designed to hold conductors and receptacles assembled in the field or at the factory. It is much like surface raceway, except that the receptacles used in the raceway do not use boxes and are usually prewired. These assemblies are installed much like surface raceways and are subject to the same general code restrictions.

**Flat Conductor Cable.** A flat conductor cable (Type FCC) consists of three or more flat copper conductors placed edge to edge, separated and enclosed within an insulating assembly, and covered with carpet squares. A compiete system includes the cable, associated shielding, connectors, terminators, adapters, boxes, and receptacles.

Type FCC systems are approved for general purpose circuits and appliance branch circuits and are rated not over 300 volts between conductors or 30 amps.

They are NOT approved for outdoors, wet locations in a corrosive atmosphere, hazardous locations, residences, schools, or hospital buildings.

The installation is fast and simple:

*a*. First remove the floor covering.

*b*. Roll out the bottom shield from the junction and feed box, and fasten the shield on the bare floor with adhesive tape.

*c*. Roll out the type FCC cable on top of the bottom shield.

*d*. Make all connections to the cable using the special connectors.

*e*. Install the metal top shield on the cable, connectors and insulating ends, then tape the shield down.

*f*. Finally, replace the carpet tiles.

Before you can install any of the extensions discussed thus far, you must find out if the circuit you are extending has the capacity for the extra load. You can determine this by subtracting the present connected load from the fused capacity of the circuit. If all of the outlets on the existing circuit do not have connected loads, you should use their average load to obtain the connected-load figure. When you know for sure that the existing circuit has the capacity, you can add the extension.

**Exercises (263):**

1. What is the purpose of a circuit extension?

2. Describe a nonmetallic extension.

3. Describe an underplaster extension.

4. Which type of circuit extension is used primarily where appearance is a factor?

5. Give the NEC definition of a multioutlet assembly.

6. Place the letter T in front of the correct statements pertaining to circuit extension installations and the letter F in front of false statements.

_____ a. Nonmetallic extensions can be installed in any building.

_____ b. Nonmetallic extensions cannot be installed in attics, unfinished basements, or roof spaces.

_____ c. Splices can be made in nonmetallic surface extensions as long as approved devices are used.

_____ d. Nonmetallic extensions must be supported at intervals not to exceed 8 inches and cannot be installed within 2 inches of the floor.

_____ e. Nonmetallic sheathed cable can be used as an extension.

_____ f. Underplaster extensions can be installed in any type of building.

_____ g. Types AF and MI cables may be used as underplaster extension.

_____ h. Surface raceways are used as extensions where appearance is important because they take up less space.

_____i. Surface raceways are supported with flathead screws through mounting holes as a supporting clip.

_____j. Surface raceways come in two types, metal and nonmetallic, and are generally used in only dry locations.

_____k. Multioutlet assemblies are surface or flush raceways mounted in much the same way as surface metal raceways and are subject to the same code restrictions.

_____l. Type FCC cable can only be installed in single residential buildings or office buildings.

# Meters and Test Equipment

WHEN WORKING with electricity, you often need to know something about a circuit or piece of equipment that you cannot visually detect. You need various meters and other test equipment to check for the proper voltage, current flow, amount of resistance, and to determine whether the wiring is defective. Without knowing just how these test instruments operate, you may be able to connect them and take a reading. However, you need to know more than just how to read a test instrument.

## 8-1. Meters

Meters are used in repairing, maintaining, and troubleshooting electrical circuits and equipment. The best and most expensive measuring instrument is of no use to you unless you know what you are measuring and what each reading means. You must remember that the purpose of a meter is to measure quantities. When a meter is connected to a circuit, it must not change the condition of the circuit.

### 264. Specify the operating principles of the two basic meter movements.

**Meter Movements.** Meters are either self-excited or externally excited. Self-excited meters operate from their own power source. Externally excited meters get their power from the circuit to which they are connected. Most common meters (voltmeters, ammeters, and ohmmeters) that you use in your work operate on the electromagnetic principle.

There are several types of meter movements. However, the most practical meters manufactured today use either the galvanometer movement or the dynamometer movement. Both of these movements depend on a magnetic field produced by current flowing through the meter movement itself.

*Galvanometer movement.* The application of electromagnetism produced the first practical electric meter. It is called a galvanometer (or D'Arsonval meter, so named after its inventor). The basic galvanometer is used to measure a very small amount of current and voltage. With certain modifications, the galvanometer movement can be adapted for practical use in voltmeters, ammeters, and ohmmeters.

A simplified diagram of a galvanometer movement is shown in figure 8-1. The movement consists of a coil of fine wire mounted on a movable, aluminum bobbin (the bobbin is mounted on an iron core), a set of permanent magnets, and a pointer mounted on the bobbin. The coil and bobbin assembly is mounted on pivots that turn in tiny jewel bearings. Hairsprings are mounted on each end of the coil. The springs conduct electricity through the coil and keep the pointer at ZERO position when the coil is deenergized. The coil and bobbin assembly is mounted between the poles of a permanent magnet. One terminal on the meter is marked with a plus sign for a positive connection. The other terminal is marked with a minus sign for a negative connection. To connect the meter properly, the positive side of the power source (battery or DC generator) must be connected to the plus terminal, and the negative side to the minus terminal.

The meter movement operates on the principle that like poles repel and unlike poles attract. When the meter is connected properly to a circuit, a small current flows through the coil. The current produces a magnetic field with a north and south pole. A fixed iron core is mounted inside the coil and bobbin to insure uniform magnetic poles. These poles are in such a position that they are repelled by the poles of the permanent magnet. The repelling action causes the coil and bobbin assembly to turn clockwise against the tension of the hairsprings. The distance that the coil turns depends on the amount of current flow through the coil. The resistance of the coil is fixed, thus current flow is determined by the voltage applied.

A basic galvanometer, like the one shown in figure 8-1, is very sensitive. It operates only in the microvolt (one millionth) or the millivolt (one thousandth) range. The full voltage from a single flashlight cell is enough to damage a basic galvanometer. For this reason, galvanometers are used only in laboratory work. As was mentioned before, with certain modifications the galvanometer movement is used in practical meters that you use on the job.

*Dynamometer movement.* A meter with a dynamometer movement uses the same basic principle as the galvanometer. The main difference is that the permanent magnets are replaced by electromagnets.

Figure 8-2 shows a simple diagram of a dynamometer movement. A movable coil to which the pointer is attached is mounted between two field coils. Notice that the movable coil is connected in series with the field coils. As current flows through the coils, opposing magnetic poles are established between the movable coil and the field coils. This causes the pointer to move clockwise. Current may enter the meter movement from either end; therefore, you do not have to pay attention to polarity when connecting it to a circuit. Using the left-hand rule that you learned, trace the current flow through the movement in figure 8-2. You find that current flow in either direction establishes opposing magnetic poles between the movable coil and the field coils. Their poles change according to the way the current enters. The dynamometer movement is used to measure properties of both DC and AC circuits.

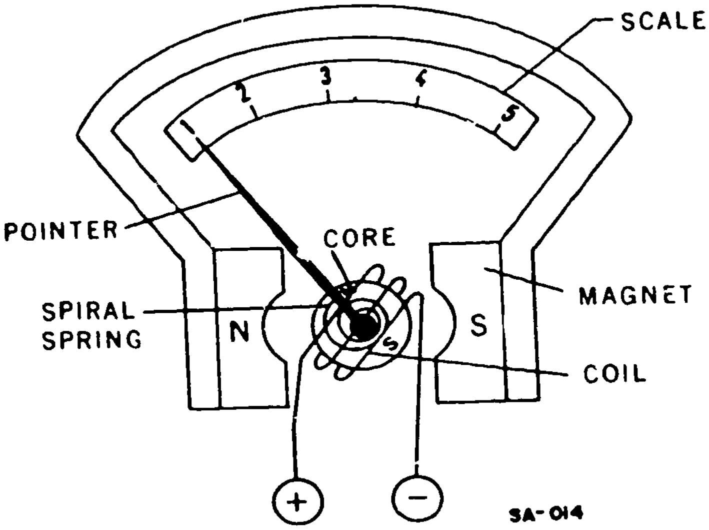



Figure 8–1. Galvanometer movement.

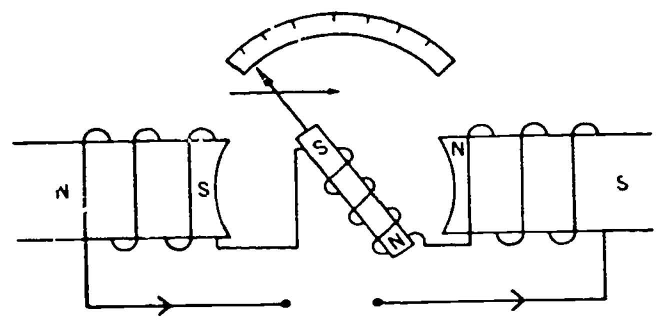


Figure 8–2. Dynamometer movement.

Exercises (264):

1. The galvanometer and the dynamometer both operate on what basic principle?

2. What is the main difference between the galvanometer and dynamometer?

3. Which basic meter movement may be used to measure both AC and DC?

**265. Differentiate between a linear and nonlinear meter scale and specify the use of meter ranges.**

**Meter Scales.** To use meters effectively, you must be able to read them accurately. Most meters have either a linear or nonlinear scale to show values.

*Linear scale.* Linear scales are used on ammeters and voltmeters. These scales are so called because they are divided into equal divisions for the full range of the meter. For example, if the full range of the meter is from 0 to 50 (amps or volts), the scale may be divided in 5- or 10- amp or volt divisions and numbered accordingly (see fig. 8-3). As you can see, there is a further breakdown of the scale between the numbered divisions. To find out what each of the smaller marked units represents, you must divide the difference between the two numbered divisions by the number of smaller units.

In figure 8-3, each of the smaller units represents 1-tenth of the numbered division; therefore, each unit is 1 amp or 1 volt. This will hold true across the full range of the meter. The pointer in figure 8-3 shows 14 amps or volts.

*Nonlinear scale.* A nonlinear scale is one in which the divisions are not equal; that is, the graduations across the scale are not the same. An ohmmeter is an example of the nonlinear scale (see fig. 8-4). Note that, on the low end of the scale at the right, the divisions are much larger than those on the high end of the scale at the left. As you can see, the numbered divisions are not all the same length or value. To find out what each marked unit represents, use the same method you used with the linear scale.

No matter which meter you are using or which scale is involved, there are two things you must remember. The first is to avoid false readings. Since the meter divisions are small and the meter pointer is raised above the scale, reading the pointer position from an angle will not give you an accurate reading. It can be off as much as one scale division. This type of false reading is called parallax. The best way to avoid this is to make sure you are looking straight at the face of the meter when taking a reading.

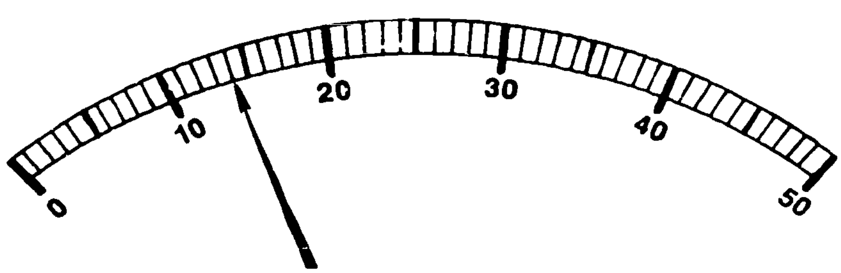



Figure 8–3. Linear meter scale.

**OHMS**

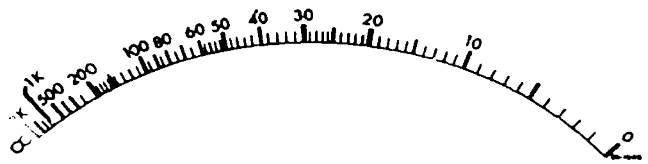



Figure 8-4. Nonlinear meter scale.

The second thing to remember is to use all the meter ranges to avoid meter damage and to get the most accurate reading possible. Most meters used on the job have two or more ranges. As an example, you might have a voltmeter with one range from 0 to 50, one from 0 to 100, and one from 0 to 500. These ranges enable you to pick a scale that is adequate for the measurement to be made without a full-range deflection of the pointer that might harm the meter. It also lets you use a scale where the final pointer reading is near the center of the scale. Meter readings near the middle of the scale are more accurate than those at the ends. Take the first reading of an unknown value on the highest meter scale, and then move the scale selector down until you get to the right scale range.

**Exercises (265):**

1. What type of meter(s) use linear scales?

2. What is the difference between a linear and a nonlinear scale?

3. How do you determine the value of the unmarked divisions of a scale?

4. What does the term "parallax" mean?

5. What range of a multirange meter should you use when checking unknown values?

6. Why should you try to get a pointer deflection that is near the center of the scale?

**266. Relate the function or operating principle to the appropriate type of meter.**

**Voltmeter.** The voltmeter is designed to measure the potential difference between two points. It will measure AC or DC voltages according to the function you select. Most voltmeters use a galvanometer-type movement connected in series with a high resistance unit. The purpose of the high resistance is to limit the current flow through the meter movement because most voltmeters give a full-scale deflection with less than 0.01 ampere flowing through the movement. Because the resistance of the meter is fixed, the current flow and the amount of deflection of the pointer depends upon the voltage applied to the terminals of the meter. The pointer indicates, on the scale, the voltage drop across the unit being measured. Figure 8-5 shows the internal wiring of a voltmeter.

When troubleshooting a system with a voltmeter, you would normally connect it in parallel with the electrical unit to be tested. For example, if you are checking the voltage at a DC voltage control panel, connect the plus (+) terminal of the voltmeter to the positive side of the panel and the minus (−) terminal of the voltmeter to the negative side of the panel. You must do this so that the pointer will point in the right direction. A word of caution—never connect a voltmeter to a source of voltage that exceeds its calibrated scale.

Note the selector switch at the lower right portion of the schematic in figure 8-5. This switch permits you to place various fixed resistances into the voltmeter circuit so that wide ranges of voltages can be measured with one small, compact instrument. Otherwise, you would have to use either a meter with a much larger scale or many separate instruments with appropriate internal resistance. When measuring the voltage of any circuit, you should always select the highest range indicated by the selector knob. If the needle moves only a small amount, you can then move the knob to lower ranges to get a more sensitive reading. This method of starting at the highest range provided by the selector prevents violent needle deflection and internal circuit damage to the meter. The meter would be damaged if you accidentally measured a high voltage with the switch set at a low range.

**Ammeter.** Ammeters are used to measure the electrical current flowing in a circuit. This instrument uses about the same internal movement as the voltmeter. Instead of current-limiting resistors in series with the movement, the ammeter uses a shunt, or current bypass, in parallel with the movement. This arrangement is shown in figure 8-6.

As you know, a shunt is a resistor made of a special alloy which changes very little in electrical resistance, even though there may be definite temperature changes. The movement of the meter and the resistance of the shunt are proportioned so that most of the current flows through the shunt. Only a small fraction of the current flows through the movement—just enough to give a full-scale deflection when the total current is equal to the maximum range of the ammeter. An example of an ammeter with an external shunt is shown in figure 8-7. With the shunt shown, it is a 300-ampere ammeter. If a movement is used that requires 0.01 ampere to give full-scale deflection, only 0.01 ampere will

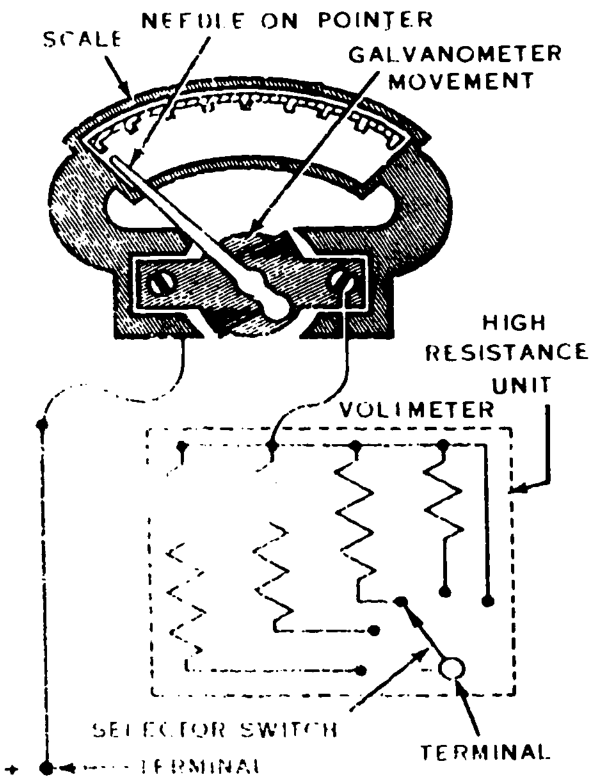



Figure 8-5. Internal wiring of a voltmeter.

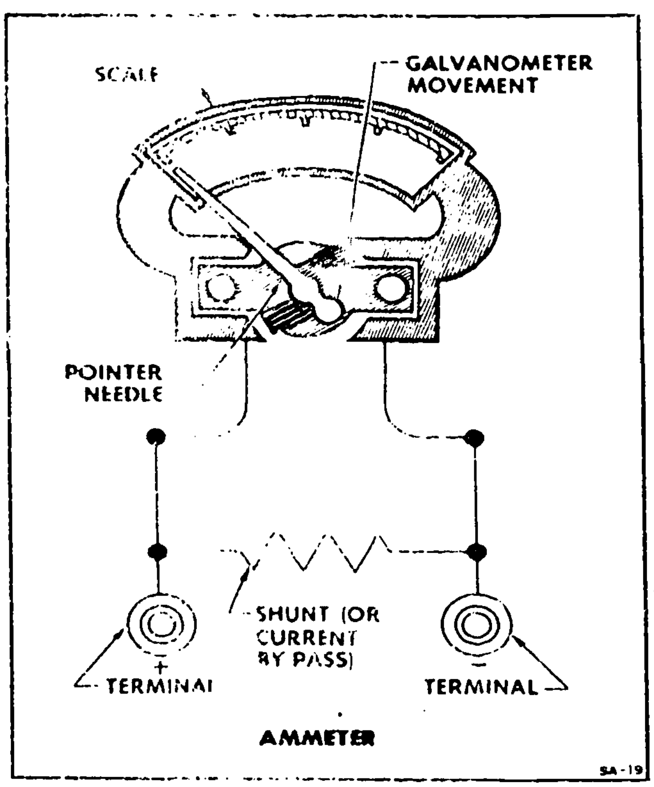



Figure 8-6. Internal wiring of an ammeter.

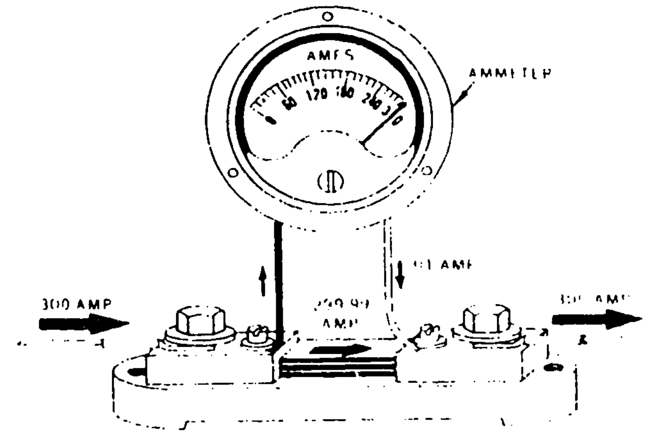



Figure 8-7. Ammeter with external shunt.

flow through the meter when 300 amperes is measured. As you can see, the remaining 299.99 amperes will bypass through the shunt.

Unlike the voltmeter, an ammeter should always be connected in series with the load. The positive (+) terminal of the ammeter is connected to the positive side of the load. Never connect the leads across the terminals of a battery or generator—this would immediately burn out the meter. An ammeter is never used, for example, in continuity testing because it has very low resistance and would short-circuit the battery.

**Ohmmeter.**—An ohmmeter consists of a meter movement, a network of resistors, and a small dry-cell battery as a source of voltage. The internal wiring is shown in figure 8-8. Ohmmeters measure the electrical resistance of a unit or a circuit. Since the voltage to the ohmmeter is constant (with the dry-cell battery) the current through its movement (and hence the deflection of the pointer) depends upon the resistance of the unit being tested. The meter, therefore, shows the resistance of the wire, cable, or unit being checked. It is calibrated to read this resistance directly.

In troubleshooting, the ohmmeter, although primarily designed to measure resistance, is useful for checking continuity. Let's take another look at the internal wiring diagram of our ohmmeter in figure 8-8.

Remember that the ohmmeter has a small battery for its source of voltage. The fixed resistors are of such value that if the test probes are shorted together, the meter will read full scale, which in this case is zero. The variable resistor, in parallel with the meter and the fixed resistors, compensates for changes in the voltage of the battery. On the meter control panel, the variable resistor has a zero adjustment for the indicator. On the face of the meter, there may be several calibrated scales. These are made possible by the various values of resistances and various battery voltages. When you use the ohmmeter, you first select the scale you need by a switch on the meter panel. Each scale will read low resistance at the upper end. The greater the

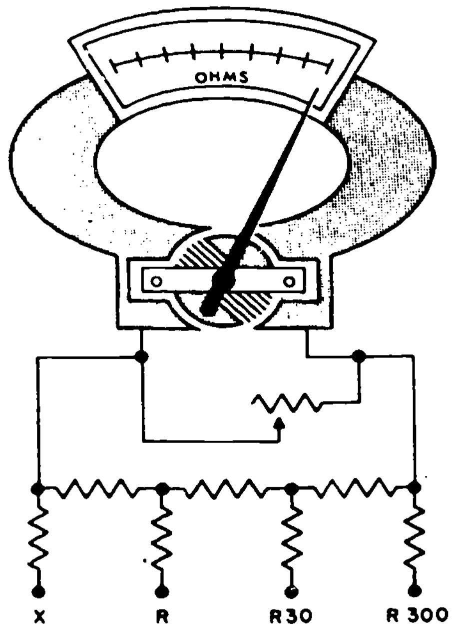



Figure 8-8. Internal wiring of an ohmmeter.

resistance in a circuit, the less deflection you will see on the indicator. Never connect an ohmmeter into a live circuit. This will damage the meter.

**Megohmmeter.** The megohmmeter (or megger, as it is more commonly called) is used for measuring the resistance of insulating material. As its name indicates, the megohmmeter gives resistance readings directly in millions of ohms. One megohm equals 1 million ohms. The megohmmeter is used primarily to indicate the insulation resistance of cables, motor and generator windings, transformer windings, and circuits in conduit.

The megohmmeter may consist of a small, handcranked DC generator and a meter movement much like the one used with the ohmmeter. If a generator is used, a centrifugal clutch is installed between the handcrank and the generator, as shown in figure 8-9. The clutch is fixed so that no matter how fast you crank the generator, the output voltage is 500 or 1000 volts, depending on what it should put out. Instead of a generator, some meggers may use a battery as a power source. Although the voltage output is high, both sources of power produce only a small current flow. Since a megohmmeter has its own power source, like an ohmmeter, it should never be used on a live circuit. To do so will more than likely ruin the meter.

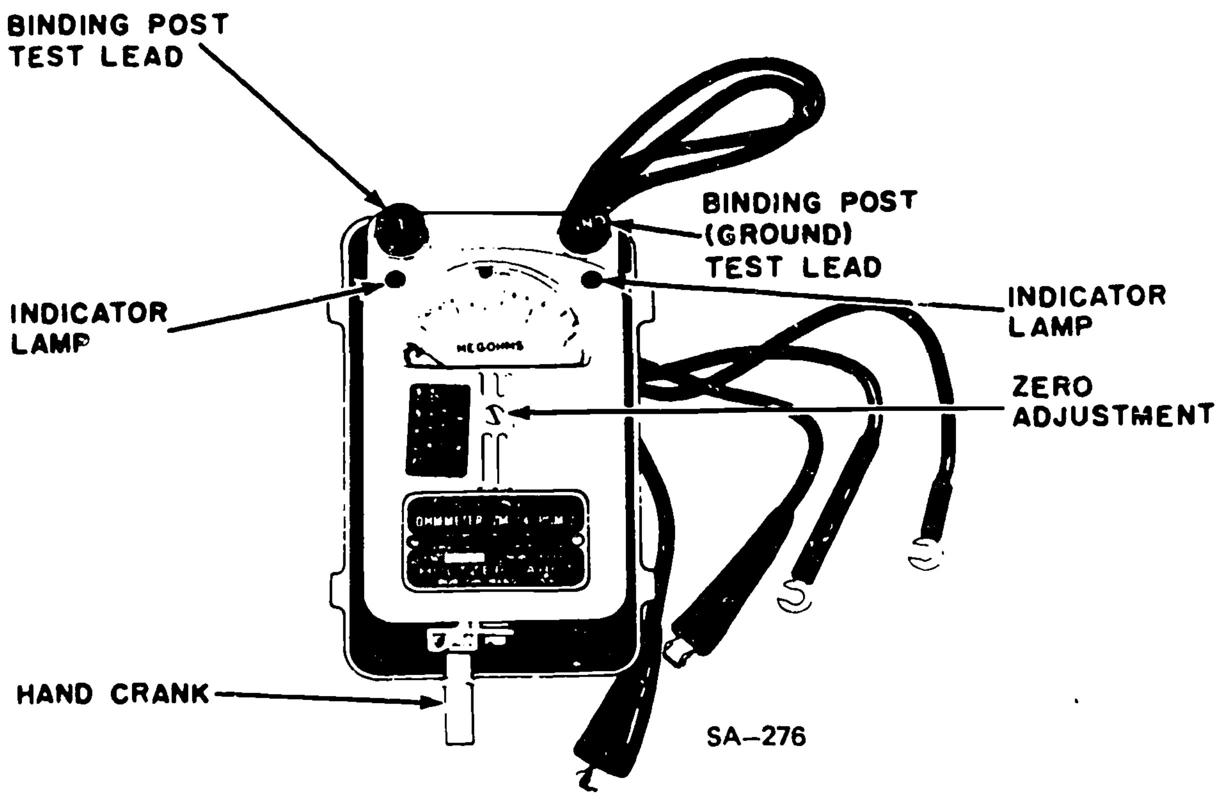



Figure 8–9. A megger insulation tester.

**Exercises (266):**

1. Match the items in column B to their proper function or principle of operation listed in column A by placing the corresponding letter in the space provided. A letter may be used more than once.

| *Column A* | *Column B* |
|---|---|
| ______(1) Used to measure the potential difference between two points. | a. Ammeter. |
| ______(2) Uses a small dry-cell battery as a source of voltage. | b. Ohmmeter. |
| ______(3) Should always be connected in series with the load. | c. Voltmeter. |
| ______(4) Used to measure the resistance of a circuit or device. | d. Megohmmeter. |
| ______(5) Used to test the insulation of a circuit. | |
| ______(6) Should never be used on a live circuit. | |

**267. State the procedures for setting up a typical multimeter for use as an ohmmeter, voltmeter, or ammeter.**

**Multimeters.** The multimeter is a combination of two or three meters that has only one meter movement. Each multimeter has a selector or function switch that is used to set up the meter movement for a specific purpose. Some examples of multimeter combinations used in the Air Force are shown in figures 8-10 through 8-13.

Figure 8-10 is a volt-ohm-ammeter. Figure 8-11 is a volt-ohmmeter that can be used as an ammeter if an external shunt is added. Figures 8-12 and 8-13 are voltmeter/clamp-on ammeter combinations that can be used to take current readings without connecting the ammeter in the circuit. To measure current in a conductor, open the clamping jaw, place it around the conductor, close the jaw, and read the meter. The laminated steel jaws of the meter act like the core of a transformer, with the conductor being measured as the primary and a coil in the meter as the secondary. The magnetic field in the primary induces a voltage in the secondary, which the meter converts to a current reading. The more current there is in the primary (conductor), the more voltage is induced in the secondary and the higher the meter reading.

Multimeter combinations are not limited to those shown here. There are a few others, such as the volt-ammeter and volt/ohm/clamp-on ammeter. Some of the multimeters also use the digital readout in place of the standard meter scales. To cover all the different multimeters would take a full volume; therefore, the text will be limited to setting up a typical multimeter for each function. The PSM–6 multimeter shown in figure 8-10 is actually three meters in one case. It is an ohmmeter, a voltmeter (AC and DC), and an ammeter, but it can be used for only one function at a time.

*Ohmmeter function.* First, let us see how the PSM–6 is set up to be used as an ohmmeter. Figure 8-10 shows the face panel of the meter and the controls. The PSM–6 has two selector switches: function and range. Since we want to measure resistance, the function switch should be set for OHMS.

The range switch has seven positions. You will note in the figure that the horseshoe-like symbol, which is the Greek letter omega Ω representing ohms, is missing on the switch are not used when measuring resistance. Most of the time, you will start a measurement with the range switch in the OHMS TIMES ONE (Ω X 1) position and work up to the most accurate scale.

The PSM–6 has a pair of leads. One lead is red (positive); the other is black (negative). As you can see in the figure, the PSM–6 has two jacks on the lower part of the front panel. To prepare the meter for use, simply insert the red lead into the red jack and the black lead into the black jack.

Before proceeding you must remember to use caution when using the ohmmeter function of the PSM–6. Never connect an ohmmeter into a hot circuit (power applied).

Now, before you make a measurement with the ohmmeter, it must be zeroed. To do this, short the leads together to cause full-scale deflection. If the pointer does not point directly at the zero scribe mark, you must make the zero adjustment. Turn the ohms zero knob until the pointer points directly at the zero mark. A very important factor to remember when making an accurate resistance measurement is to zero the meter each time you select a new range scale. Also, when you make a resistance measurement, consider these points:

*a.* You may have to break a soldered connection if the resistor to be tested is in a parallel circuit. In other words, the resistor must be isolated.

*b.* The meter leads must make good contact with the resistor leads. You should remove any dirt, grease, varnish, paint, or any other material on the resistor leads that may prevent current flow.

*c.* Don't allow body resistance to distort your ohmmeter reading by touching the ends of the leads with your fingers. Keep your hands on the insulated portions of the leads.

Since full-scale deflection is caused by zero resistance, it can be said that the deflection of the meter is inversely proportional to the resistor being tested. For a small resistance, the deflection will be slightly less than that of zero resistance; for a large resistance, the deflection will be considerably less. This difference in deflection indicates that the left side of the ohm scale shows high resistance, and the right side of the scale shows low resistance. With rare exceptions, the ohms scale is always read from right to left. Zero resistance is indicated on the right side of the scale. Therefore, you must begin from the zero point and work left until you come to the pointer. When you read the meter, you must also read the position of the range switch and multiply the reading on the meter scale by the range-switch setting.

As you can see in figure 8-10, the calibrations, or scribe marks, of the ohm scale are crowded on the left side, which makes accurate reading difficult. For this reason, it is best to use a range in which the pointer will fall in the right half of the scale.

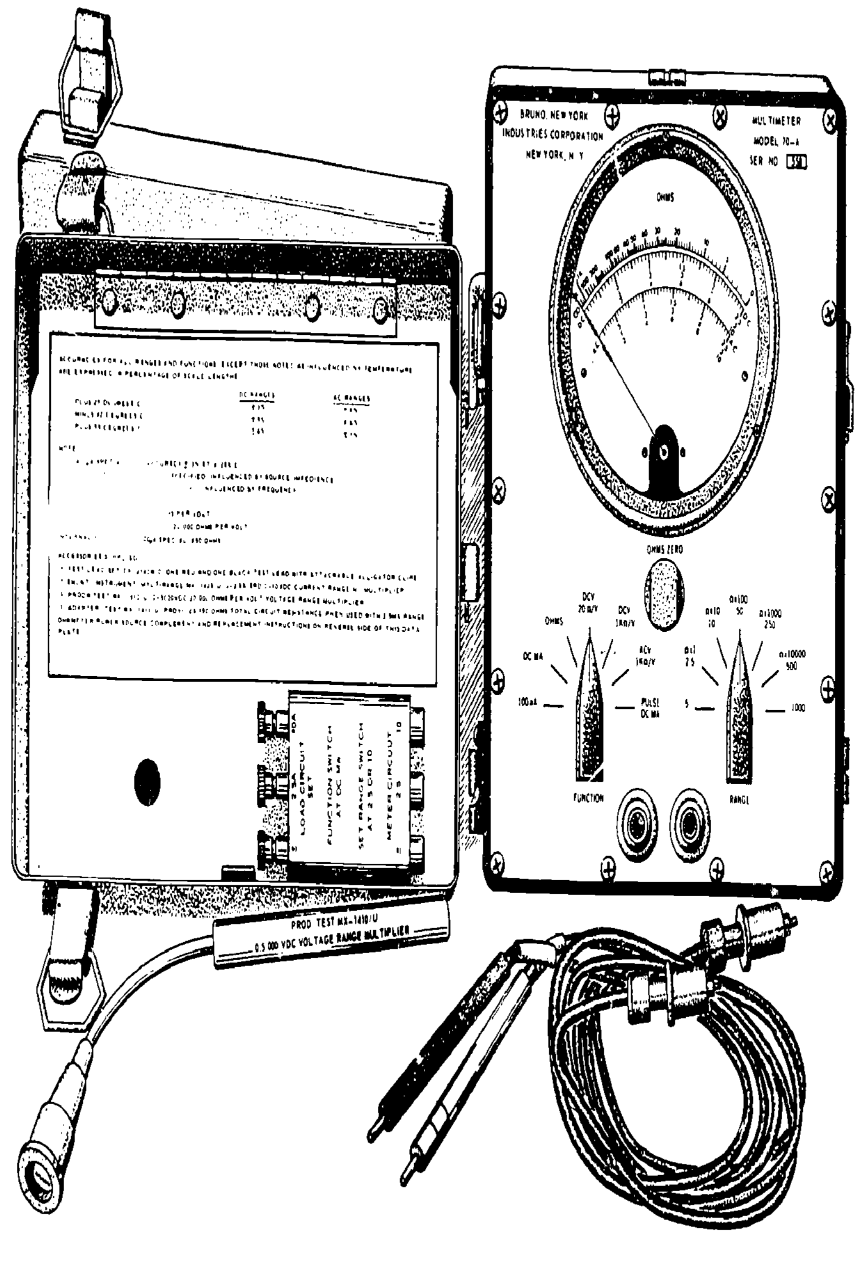



Figure 8-10. PSM-6 multimeter.

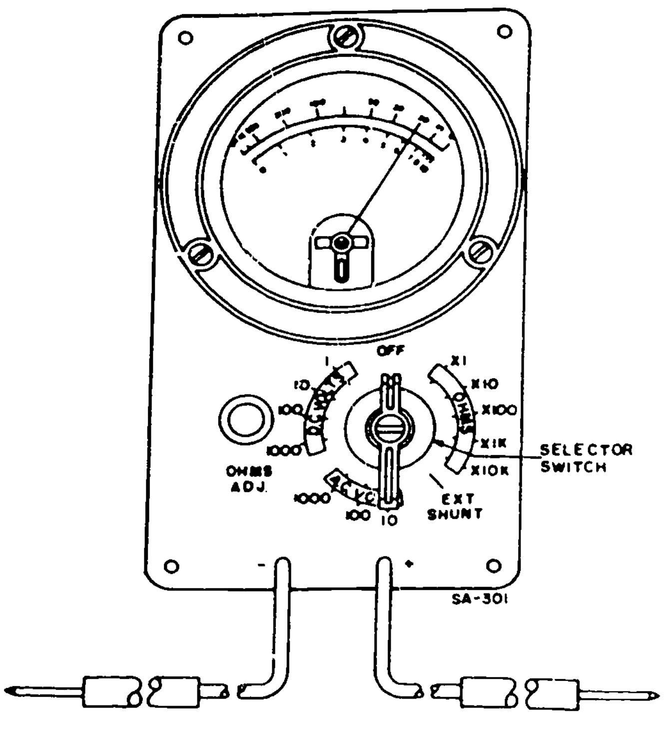



Figure 8-11. AN/URM 105, multimeter.

As an ohmmeter, the PSM–6 is a very handy instrument. It appears to be fairly rugged; however, inside there are many delicately balanced precision parts so be careful with it. When you finish using the ohmmeter, be sure to place the function switch to a position other than OHMS before storing it. When it is stored with the function switch in the OHMS position, the batteries discharge like the batteries of your transistor radio when you leave it on all of the time. The leads should also be removed and stored for their protection. There is a storage compartment in the meter cover for meter accessories.

*DC voltmeter function.* The PSM–6 can also be used as a DC voltmeter if the function switch is placed in either of two positions: DC/1KΩ/V or DC/20KΩ/V. The meter leads, as in the operation of the ohmmeter function, should be connected to the ' er i. ks of co esponding co .o nt reverse i deflection.

s you shou' now, when a meter is connected in a circuit, it beco ircuit component. Since all meters have some resistance, they will alter the circuit condition by slightly changing the current. The resistance of the voltmeter is rather high and depends on the position of the function switch. The DC/20KΩ/V position gives a much higher meter resistance than the DC/1KΩ/V position, and the higher meter resistance gives a more accurate meter reading. For this reason, you should use the highest meter resistance possible. In earlier models, voltmeters contained only a 1,000-ohms-per-volt function, and tables of standard voltage values were established with this function. Therefore, many of the tables of standard voltage values you will find in technical orders were made using the 1000-ohms-per-volt position. If you wish to compare your readings to standard values, you will need to use the DC/1KΩ/V position. But remember that the DC/20KΩ/V position gives the most accurate reading.

Now that we have the function switch set and the master leads connected, let's discuss the range switch and the scale on the meter to be used. When measuring DC voltages, you can select one of seven ranges with the range switch: of the range switch determines the maximum value represented on the meter. When measuring DC voltages, use the black DC scale. For example, assume that you wish to measure 30 volts DC. In this case, set the range switch to the 50 position; the meter needle will rise to a little more than half-scale. Then the digit 5 on the scale represents 50 volts, and the 3 (to which the needle will move) represents 30 volts.

When measuring a known DC voltage, try to use the range that will cause midscale deflection. If the leads were connected to the circuit backwards, the meter needle would try to move in the reverse direction and could be damaged by hitting the left-hand meter stop. If in doubt, check the polarity by momentarily touching the leads to the circuit. If the needle moves to the right, the polarity connection is correct.

For DC voltage of a range higher than 1000 volts, an accessory PROD TEST, as shown in the bottom center of figure 8-10, is provided in the PSM–6 accessory kit. Prod Test MX–1410/U can increase the meter range to 5000 volts.

The procedure for connecting the MX–1410/U with the PSM–6 is as follows: Place the function switch to 500. Connect meter leads to the PSM–6 (same as for ohmmeter or voltmeter). Connect the negative lead to the negative point of the circuit under test and the positive lead to the pin jack of MX–141/U. Connect the prod test to the source of voltage under test. Read the DC scale, using five digits (should be read as 5000).

*AC voltmeter function.* The PSM–6 can also be used as an alternating-current voltmeter. The method of connecting the meter leads is the same as with the DC voltmeter, except that polarity need not be observed. You should use the same safety precautions as with the DC voltmeter (disconne power b fore connecting test leads, etc.). An A n the range of 0–000 volts, ivity of 1000 ohms per volt. The method for selectin measuring is as follows: place the function switch to ACV/1KΩ/V. Use the range switch just as you did when measuring DC voltage. Now, you must use the AC scale on the meter. The numbering system is similar to that of the DC voltmeter readings.

When you do not know the applied voltage, using either the AC or DC voltmeter, always set the range switch to the highest setting. This will insure that you do not damage the meter movement.

You will seldom be required to make a current measurement with a PSM–6. Should this be necessary, refer to TO 33A1–12–2–1.

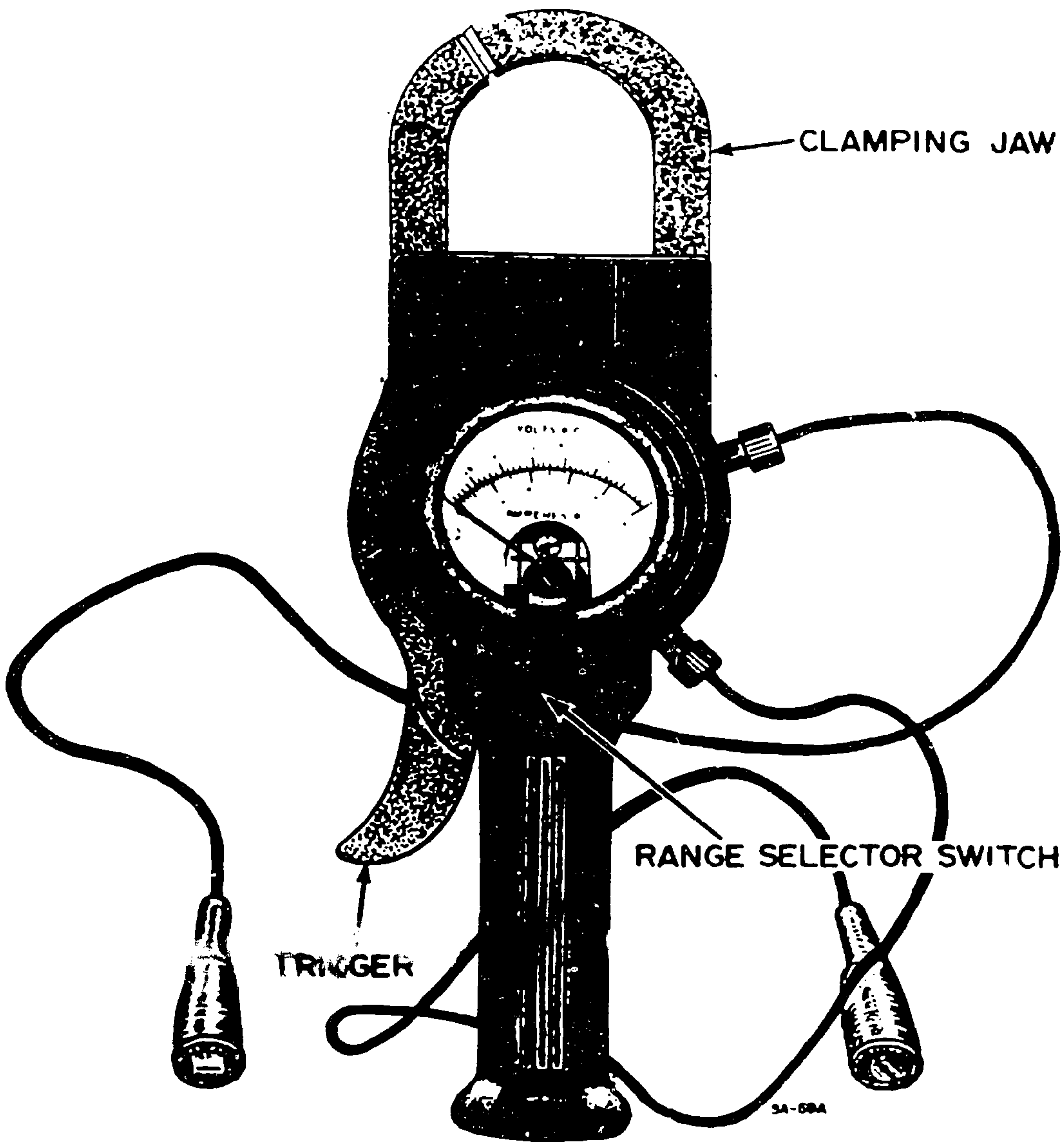



Figure 8-12. Clamp on multimeter

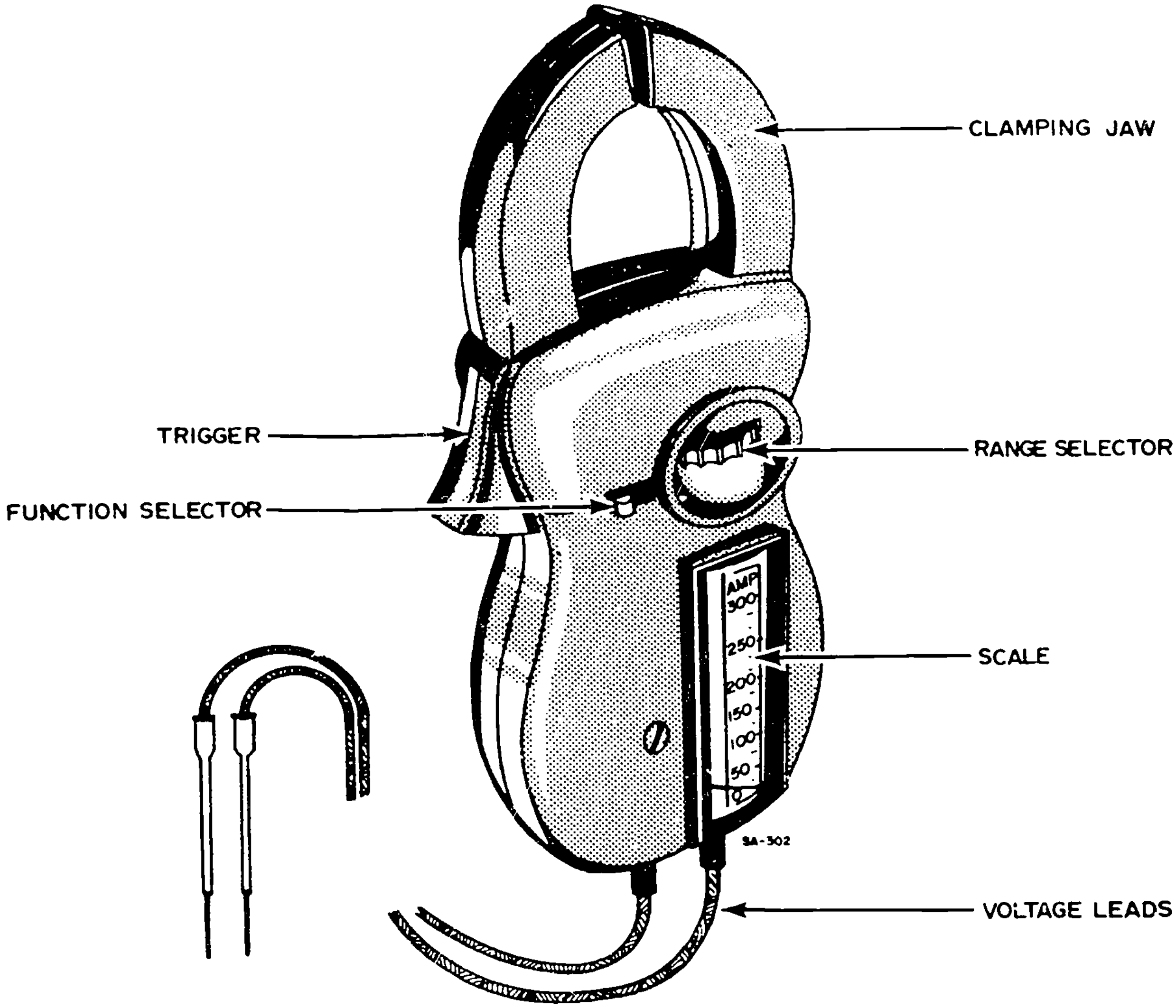



Figure 8–13. Volt-amp multimeter.

**Exercises (267):**

1. State the setup procedures for the PSM–6 ohmmeter.

2. What precaution must you observe when using an ohmmeter?

3. How should the ohmmeter be stored?

4. How is the PSM–6 DC voltmeter function set up?

5. What are the procedures required to change the PSM–6 from reading DC voltage to AC voltage?

6. Mark the following statements true (T) or false (F). Correct false statements.

_____ a. The most accurate DC voltage reading is given when the function switch is in DC/1KΩ/V position.

_____ b. When using the AC voltmeter, you need not observe the polarity when placing the leads in the circuit.

_____ c. To measure VDC, set the range switch to 2.5 and move up range for a more accurate reading.

_____ d. If you need to read DC voltages above 1000 volts, use a Prod Test MX–1410/U.

## 8-2. Test Equipment

In addition to the common meters previously discussed, there are several other pieces of test equipment you may use in your work. Some of these test devices have their own source of power, and others depend on an external source. There may be times when you are testing a circuit that you need to know only if the circuit is complete or if voltage is present. In such cases, or when a meter is not available, these devices can be quite useful.

**268. Identify the function of voltage indicators, continuity test sets, and circuit breaker and overload relay testers.**

**Voltage Indicators.** These devices provide a very convenient and compact way to find out whether a circuit is live. Some may also be used to find the polarity of DC circuits or to find out whether a circuit is AC or DC. There are a number of types, shapes, and sizes of indicators, all of which serve the same purpose. A typical voltage indicator is shown in figure 8-14. With the test leads connected to a circuit, the presence of voltage will be indicated by the glowing of a neon light. This light is energized by the live circuit and will show the approximate amount of voltage on the scale. Others show the amount of voltage by way of a pointer on the scale. No matter which indicator is used, it must be connected in parallel with the source of power.

If you do not have an indicator of the type described, in an emergency you can make one that will show you whether voltage is present. It is called a test/lamp and is merely a weatherproof rubber light socket with an incandescent lamp. The lamp used should be of the highest voltage rating of the circuit to be tested. Never use an indicator or test lamp on a circuit where you suspect the voltage might be higher than that for which the lamp is rated.

**Continuity Test Set.** The continuity test set is used to check circuits for broken conductors or open connections. It can also be used to check for shorts or grounds. It is used in place of an ohmmeter when it is not necessary that you know the amount of resistance in the circuit. Figure 8-15 shows you how to connect a battery and a low-voltage buzzer or bell to use as a continuity test set. Note that the bell and battery are in series. To complete the circuit and ring the bell, you have to short the test leads or test a complete circuit. If you are checking a circuit that is open, the bell will not ring. It is important to remember that this set, like an ohmmeter, must never be connected to a live circuit. To do so might blow up the power source or cause a severe shock.

**Circuit Breaker and Overload Relay Tester.** The circuit breaker and overload relay tester is a self-contained portable unit, operated by an external 120 volts, 60 Hz power supply. The tester is used to calibrate molded case circuit breakers and overload relays. It has an output capacity rated from 4.5–200 amperes.

The test unit is placed in series with the device being checked. The required amperes are dialed into the device and register on the tester ammeter. If the device being checked is working properly, the device should trip-out at ± 15 percent of the device rating. The tester will find weak devices that trip early causing unnecessary nuisance tripping and potential fire hazards from devices that operate over their rated amperes.

Troubleshooting or circuit analysis using the test equipment and meters covered in this chapter will be covered again in Chapter 9.

Remember that the meters and the items of test equipment you use from time-to-time are delicate precision instruments, and must be handled with care. Unreliable or inaccurate instruments can cause you to make costly errors; therefore, the care of meters and test equipment is extremely important to you. Before you attempt to use an unfamiliar piece of equipment, read the instruction manual and follow its instructions carefully. Some test instruments may require special handling; others require special storage.

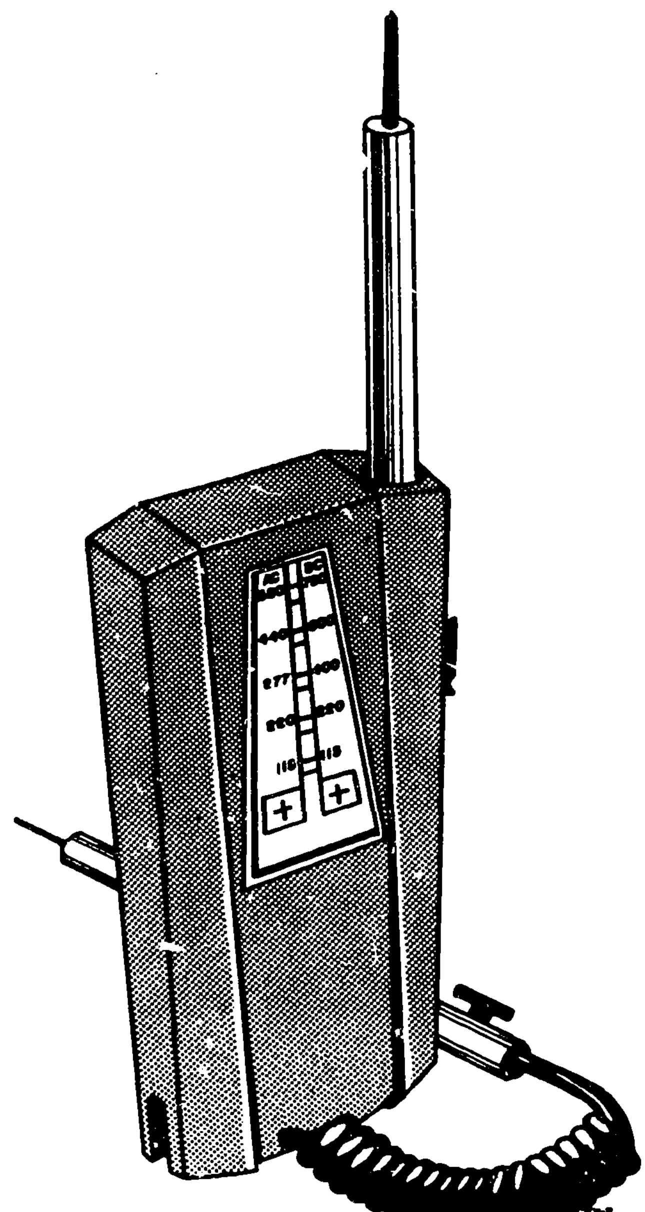


Figure 8–14. Voltage indicator.

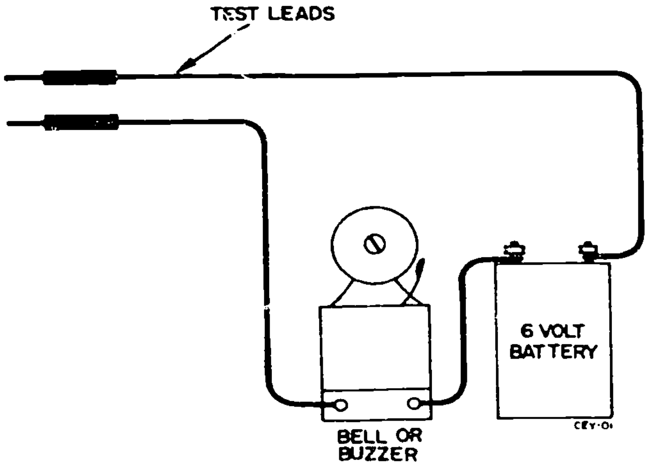



Figure 8-15. Continuity test set.

**Exercises (268):**

Mark the following statements true (T) or false (F), and explain why the false statements are incorrect.

_____ 1. Voltage indicators are used only for indicating the pressure of voltage.
_____ 2. Voltage indicators have an internal power source.
_____ 3. When using a test lamp, any size lamp will do.
_____ 4. The continuity test set is used for locating opens, shorts, or grounds.
_____ 5. The continuity test set can be used on live circuits.
_____ 6. The circuit breaker and overload relay tester is used to check overcurrent protection devices.

# Distribution System Maintenance, Troubleshooting and Repair

ABOUT HALF of your time as an electrician will be spent performing preventive maintenance and troubleshooting circuits to find faults. Once equipment is installed, it is expected to remain in service for some time. A good maintenance program will insure that the equipment does have a long life. This program is part of your responsibility as an electrician.

## 9-1. Inspection and Maintenance

Regardless of the quality of installation or materials used, any functioning system is subject to unexpected breakdowns. An effective inspection and maintenance program, as discussed below, will enable you to cut downtime to a minimum.

**269. Identify the components of a distribution system that should be included in an inspection and maintenance program, and cite maintenance procedures.**

**Preventive Maintenance.** A well-planned maintenance program is merely a system of routine inspections and checks along with periodic cleaning, tightening, adjusting, and lubricating, designed to keep the system in good condition. If you follow the program, you should be able to prevent breakdowns or faults. This is called preventive maintenance. A good maintenance program for interior distribution systems will include the inspection and maintenance of conductor insulation, fittings and connections, and all electrical operating devices.

*Conductor insulation.* The insulation materials on conductors shield or protect the conductors from accidental contact with other conducting materials. Either the insulation is formed on the conductor during manufacture or it is installed during the system's installation. It is important for you to maintain these coatings or shields on the conductors. Preventive maintenance should, therefore, include periodic insulation resistance tests using a megohmmeter and visual checks to expose potential trouble locations. You may find that the wire insulation has become nicked or scraped. These areas should be taped, repaired, or replaced, and then relocated to prevent future damage.

Conductor shielding that was put on conductors during installation must also be included in your maintenance program. When the original shielding, such as a protective sleeve, tape, or a wire nut is dislodged or damaged, you should replace it. Cable or conduit supports should also be checked periodically to insure a trouble-free operating system. Loose or missing straps should be retightened or replaced.

*Fittings and connections.* To avoid the possibility of short circuits, you must periodically spot check the electrical connections and fittings. These fittings include such items as conduit couplings, connectors, and cable clamps. You must check these fittings for looseness or separation. Tighten fittings and reclamp or resupport the conduit or cable when necessary.

The conductor connections to electrical devices or other conductors must also be included in your periodic maintenance checks to determine the condition of splices, wiretaps, and terminal connections. Loose, partial connections, or partially broken connections at the screw terminals or splices of an electrical device can cause short circuits or arcing, especially if the free wire makes contact with other metallic parts that are grounded. Excessive heat is the real problem, since the heat created by the loose connections causes an increase in amperage, which in turn generates more heat.

The increased resistance resulting from a loose or poor connection also increases the voltage drop causing inefficient operation. If this increased resistance in the wire or terminal connections is high enough, the resulting heat may reach a temperature that will ignite the insulation and surrounding materials, and provide the basis for a fire. Consequently, all electrical connections you find loose, either on equipment or in circuits, must be tightened or repaired. One sign of a poor connection is corrosion. If you find such a situation, be sure to clean and retighten the connection to correct the cause.

*Devices.* The importance of periodically inspecting all electrical devices for defects cannot be overemphasized. Just a personal observation on your part can detect most serious difficulties within an electrical system. Your periodic inspections, checks, and tests of equipment and devices must include the normal operation under a specified rated load. Any device, such as a circuit breaker, which fails these tests is broken or loose in its mountings must be replaced or repaired to prevent an operational breakdown or a hazard to you and others. If breakage occurs repeatedly in specific locations, you should either replace the electrical equipment—or the device—with more suitable equipment or relocate the equipment—or device—to a more suitable place. You will have to troubleshoot the specific circuits

and equipment to locate these types of faults. Our next section will discuss the method of doing this.

**Exercises (269):**

1. What is preventive maintenance?

2. List the components of a distribution system that should be included in a good inspection and maintenance program.

3. How is conductor insulation checked, and what maintenance is required to insure good conductor insulation?

4. Which fittings should be spot checked, and how should they be checked?

5. Why is it important to check for loose connections?

6. What should a periodic inspection or test of equipment or devices include?

7. If a breakdown occurs repeatedly in a specific location, what action should you take?

## 9-2. Circuit Troubleshooting and Repair

Electrical troubleshooting is a very important part of your job. Your ability to find a faulty condition in a short period can play an important part in shortening the downtime caused by the failure. To find faulty conditions in circuits, you must do some inspecting, some calculating, and some instrument testing. A few moments spent studying the circuit diagrams before you actually start troubleshooting will simplify the task of isolating the trouble. If a circuit fails to function, use logic when you check for the fault. The trial-and-error method of finding faults in circuits is inefficient and time consuming.

**270. Identify common circuit failures and procedures for troubleshooting electrical circuits.**

The first step to take in troubleshooting circuits is to inspect the circuit visually. Check for loose connections, loose wires, abraded wires, and loose fittings.

**Capacity.** An overloaded circuit is a serious problem. Many times the electrical demand on a circuit is so great that the circuit fuses blow or the circuit breakers trip. In some cases the wrong fuses or circuit breakers are used, causing the wires to overheat and the insulation to burn off. This condition causes shorts and grounds and sets up potential fire hazards.

**Open Circuits.** An open circuit occurs in a wiring system when one or more conductors in a circuit are broken or otherwise separated. An open circuit is determined by the failure of a part or all of an electrical circuit to operate, even though the fuses may not be blown. Use the following maintenance procedure for locating the source of the trouble:

*a.* Initially, you should make a visual check for a broken or loose connection at the first dead (nonoperating) outlet in the circuit. If a defective connection is found, tighten or repair the connection.

*b.* If you do not find the trouble or open by a visual check, use a voltmeter to determine whether the circuit is live (operating) up to the point of the component.

**Short Circuits or Grounds.** A short circuit results when two bare conductors of different potential come into contact with each other. If a conductor accidentially contacts a metallic part of a wiring system, such as a motor frame or conduit, the system is sometimes said to be grounded, instead of having a short circuit. Grounds or short circuits can be (1) solid, (2) partial, or (3) floating. This situation presents a serious safety hazard, because the machinery may still operate even though it has a short circuit. This is especially true in motors and some appliances.

A solid ground or short circuit is one in which a full voltage reading is obtained across the terminals of a blown fuse when the load is disconnected from the circuit. The circuit resistance in this case is very low, and the current is very high so that the fuse will blow.

A partial short or ground is one in which the resistance between each of the phase wires or between the phase wire and the ground is partially lowered but still remains high enough to prevent enough current to blow the fuse. Grounds of this type are generally more difficult to locate than are solid grounds.

A floating ground is a condition in which the resistance of the defect in a system varies from time to time. Grounds of this type may be present in an electrical system for some time before their existence becomes known. A floating ground is indicated when fuses continue to blow on the phase side of a circuit and a circuit test shows no defects in the system. In grounds of this type, fuse trouble may not occur for several days. Then the ground recurs, and the fuses are blown again.

The procedures used to repair the troubles mentioned thus far are usually fairly simple. In the case of an open, short, or ground in NM cable, the bad section from box to box can simply be replaced using the same procedures

outlined for installation. Another method would be to cut the cable at the trouble spot, install junction boxes, and add a short piece of cable to replace the bad section. Although the latter is the cheapest, it may not be possible if the trouble is concealed. Remember, you must leave at least 6 inches of free conductor in a junction box to make the splices.

Once you find where a trouble is in a conduit system, the repair procedure is even easier. All that is required is to pull the open, shorted, or grounded conductor out and replace it with a new one. This can be done by attaching the new conductor to the one that is to be removed. In any case, a little common sense and knowledge of the NEC requirements will dictate the action you should take.

**Exercises (270):**

1. In a visual inspection of a circuit, what do you look for specifically?

2. What is meant by an open circuit?

3. If you cannot find an open, by a visual check, what is your next step?

4. What are the three types of short circuits or grounds?

**271. State procedures for troubleshooting circuits with meters.**

**Use of Meters.** Many times a visual inspection does not uncover an apparent problem; therefore, you must advance to troubleshooting with meters. In electrical troubleshooting, you will use voltmeters, ohmmeters, ammeters, and the meter that incorporates many meters, the multimeter.

The voltmeter requires that the power be connected to the circuit before testing, whereas the ohmmeter cannot be used on an energized circuit. Voltmeter tests are started at the power input end of the circuit, whereas ohmmeter tests are started at the ground end.

Electrical circuit troubles develop either in the wiring or in the operating unit. If you carefully analyze the problem and take systematic steps to locate it, you not only save much time and energy but will also often prevent damage to expensive equipment.

Either dead circuits or live circuits can be tested with instruments. Circuit defects can sometimes be located more easily by one method than the other, depending upon the type of circuit and the trouble.

*Dead circuits.* To test a dead circuit, disconnect the device from the outlet or disconnect switch. Equipment for this method of testing includes such units as ohmmeters and battery-powered test lamps. A suitable continuity tester can be made easily from a flashlight in an emergency. An ohmmeter (which contains its own batteries) is excellent for continuity testing. A basic factor to consider in choosing continuity test equipment is to use relatively low-voltage instruments, reducing the danger of sparking. (When connections are made in the presence of combustible vapors, sparking is a serious fire hazard.)

*Live circuits.* When you test live circuits, energize the circuit under test from the power source. Generally, you will test with a voltmeter. Make certain that the voltmeter is designed for the type of voltage to be tested and has a scale of adequate range. Make sure the circuit is disconnected from the power source before making the necessary circuit changes, then reapply the power. (CAUTION: Be extremely careful not to touch the hot conductors when you use this method of testing because these live points of the circuit are exposed when the junction box covers are removed.)

**Exercises (271):**

1. What is the basic factor to consider in choosing continuity testing equipment?

2. Where are the tests started when using either a voltmeter or ohmmeter?

3. What safety procedure is followed when testing live circuits?

4. What types of meters are used in: (1) a dead circuit and (2) a live circuit?

**272. State the procedures used in troubleshooting open circuits.**

**Checking for Open Circuits.** Let's troubleshoot an open circuit with a voltmeter. The power to the circuit must be turned on. The first and most logical place to check is the fuse or circuit breaker panel.

Set the voltmeter to the proper scale. If you do not know the value of the incoming voltage, set the meter to the highest scale; then work down to the proper scale. Check each incoming phase by connecting one lead of the voltmeter to the neutral and the other to each phase one at a time.

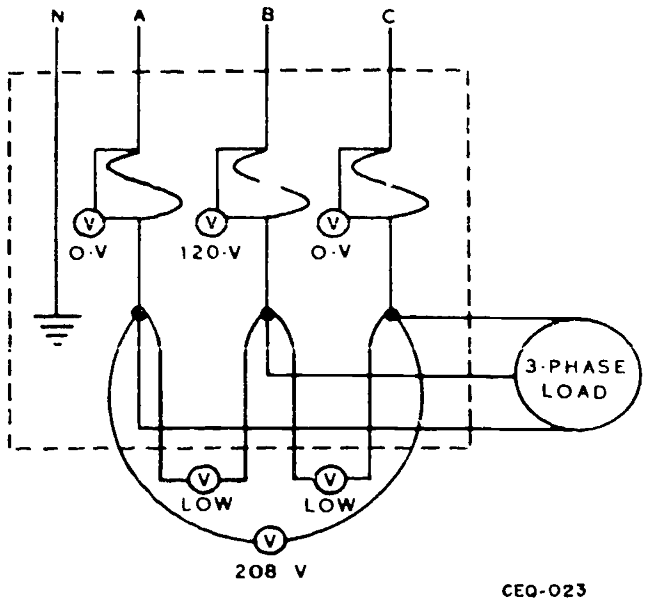



Figure 9–1. Checking for blown fuse on three-phase.

On a three-phase, 120/208-volt service, you should get 120 volts on each phase to ground. Less than 120 volts on one phase means that phase is open and you are getting a feedback from equipment connected to the load side of the panel. Sometimes there will be a slight variation of normal voltage from the different phases. Therefore, to determine whether one phase is dead, check between the phases.

To perform this test, place one lead of the voltmeter on phase A and the second lead on phase B and read the voltage. It should read approximately 208 or 240, depending upon the system. After you have taken this reading, move the second lead to phase C and take the reading. After this reading, move the first lead to phase B and take the reading. You have now read between all phases and a lower than normal reading indicates an open phase.

Which phase is dead? Assume that phase B has a blown fuse. When you take your reading between phases A and B (fig. 9-1), you get a low-voltage reading. Your next reading, between phases A and C, reads normal. But, the next reading, between phases B and C, again is a low reading. Each time you read to phase B, you get low voltage. This is a good indication that phase B is open.

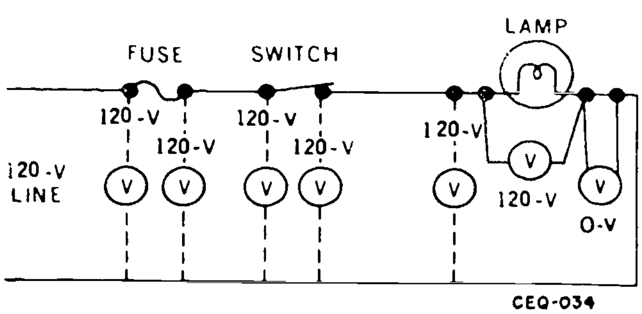



Figure 9–2. Circuit with lamp, switch, and fuse.

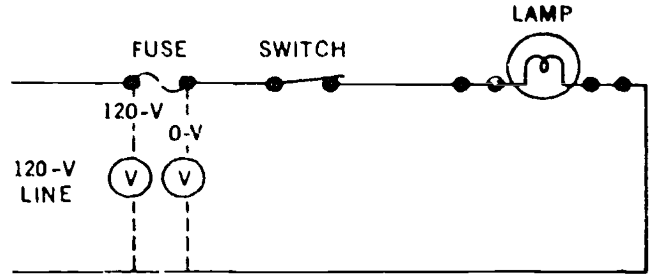



Figure 9–3. Circuit with blown fuse.

Another way to determine which phase is open is to place one voltmeter lead on the top of the fuse and the other lead on the bottom of the same fuse. If you get a voltage reading across the fuse, that fuse is open.

Assuming that everything is alright at the main panel, let's examine a single 120-volt circuit. Illustrations help explain the procedure for locating an open in a circuit. Figure 9-2 shows a circuit with a lamp in series with a single-throw switch and fuse, and the normal voltage readings at the various points of the circuit. If the lamp fails to light, check the circuit in progressive steps from the last point where voltage is known to be present, through the circuit and lamp. In figure 9-3, we have voltage at one connection of the fuse and no voltage at the other. Since the fuse is a conducting unit, normally the same voltage reading should occur between both sides of the fuse and the ground. The only conclusion in this case, then, is that the fuse is open.

Figure 9-4 shows that there is a voltage reading when the voltmeter is connected across the lamp. The logical assumption is that the lamp is inoperative. To be sure the lamp is inoperative, you must check it with an ohmmeter. Fuses, switches, and lamps are vulnerable; you should check them first in a circuit.

In figure 9-5, the lamp does not light and the voltmeter shows voltage from the ground screw of the lamp to the neutral wire. This indicates an open in the ground wire. When you connect the voltmeter at another point at the right of the lamp and no voltage is indicated, you can assume that there is an open in the wiring between this point and the lamp connection.

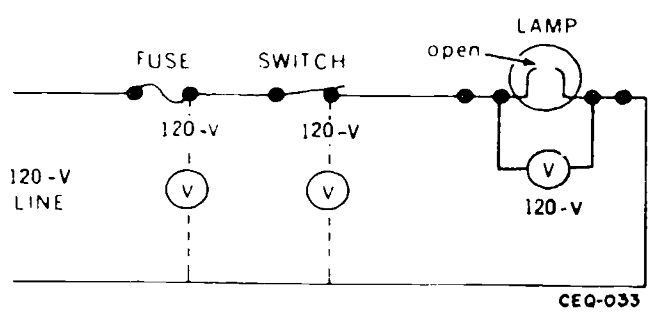



Figure 9–4. Circuit with burned-out lamp.

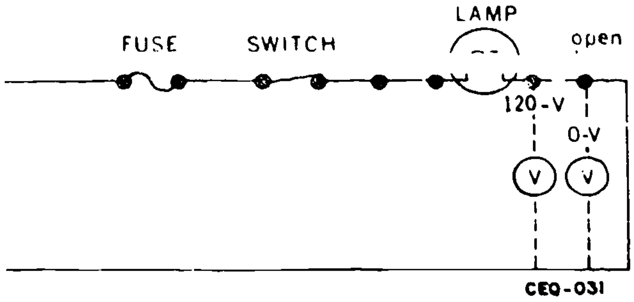



Figure 9-5. Circuit with an open.

In figure 9-6, you find two lamps wired in parallel and controlled by a double-throw switch. With the switch in the OFF (center) position, there is no complete circuit. When the switch is in the BRIGHT position, a circuit is completed through the switch and through the lamps. With the switch in this position, the only resistance in the circuit is the resistance of the lamps. When the switch is in the DIM position, the circuit is completed through the lamps as before, but this circuit has an additional resistor in series with the lamps. This added resistance causes a decrease in current flow; therefore, the lamps glow with less intensity than before.

If one of the lamps lights and the other one does not, it is not necessary to check the complete circuit to find the open. The part of the circuit up to point A is common to both lamps, and that much of the circuit must be completed for even one lamp to light. The place to begin checking the circuit is after point A in the affected part of the circuit. In a circuit such as the one shown in figure 9-6, it is best to use a voltmeter to locate the trouble. If you connect the negative lead of the voltmeter to the ground and the positive lead to point A, you will get a reading on the voltmeter scale, because point A is connected through the switch to the positive line wire. If the positive lead of the voltmeter is moved in succession from A to B to C, you are able to check the continuity of wires AB and BC. If the check at point C reveals no voltage, this indicates that wire BC is open.

You can make this same check with an ohmmeter, but several additional steps are required. First, remove power from the circuit by placing the circuit breaker and circuit switch in the OFF position. Next, disconnect the junction of wires at points A and C. Then, with one ohmmeter lead placed on the loose wire at A and the other one on B, check the continuity of the wire. When this check is made and the ohmmeter indicates a low resistance, you have continuity in the wire. But if you place one ohmmeter lead on B and the other on the disconnected wire at C and you get an infinite resistance, there is an open in this wire. (CAUTION: When you use an ohmmeter, be sure that the circuit is deenergized and is isolated to prevent reading resistance from other portions of the circuit.)

Many times you can determine the approximate location of an open by simply studying the circuit diagram before doing any actual circuit testing. For example, suppose both lamps in figure 9-6 light when the circuit switch is placed in the BRIGHT position, but neither lamp lights when the switch is placed in the DIM position. Because the lamps light when the switch is in one position, you can gather that all wires and lamps are good. The only units that could be faulty are the resistor, half of the switch, or the wires that connect the switch and the resistor. By using the ohmmeter as you did before, you can check the continuity of these parts.

**Exercises (272):**

1. Would taking a voltage reading with a voltmeter connected across a lamp indicate it was open? Explain what you would do.

2. Assuming that phase C is open in a three-phase service, describe the method used to troubleshoot this malfunction.

3. What items should you check first in a circuit?

4. What would be indicated if a voltage reading is obtained from the negative side of a component to the neutral wire? Explain.

5. When checking two lamps in parallel and one does not light, where should you begin your troubleshooting procedure?

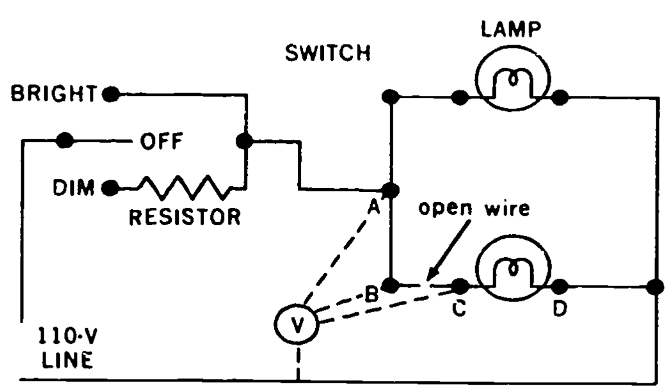



**Figure 9-6. Troubleshooting open circuit with voltmeter.**

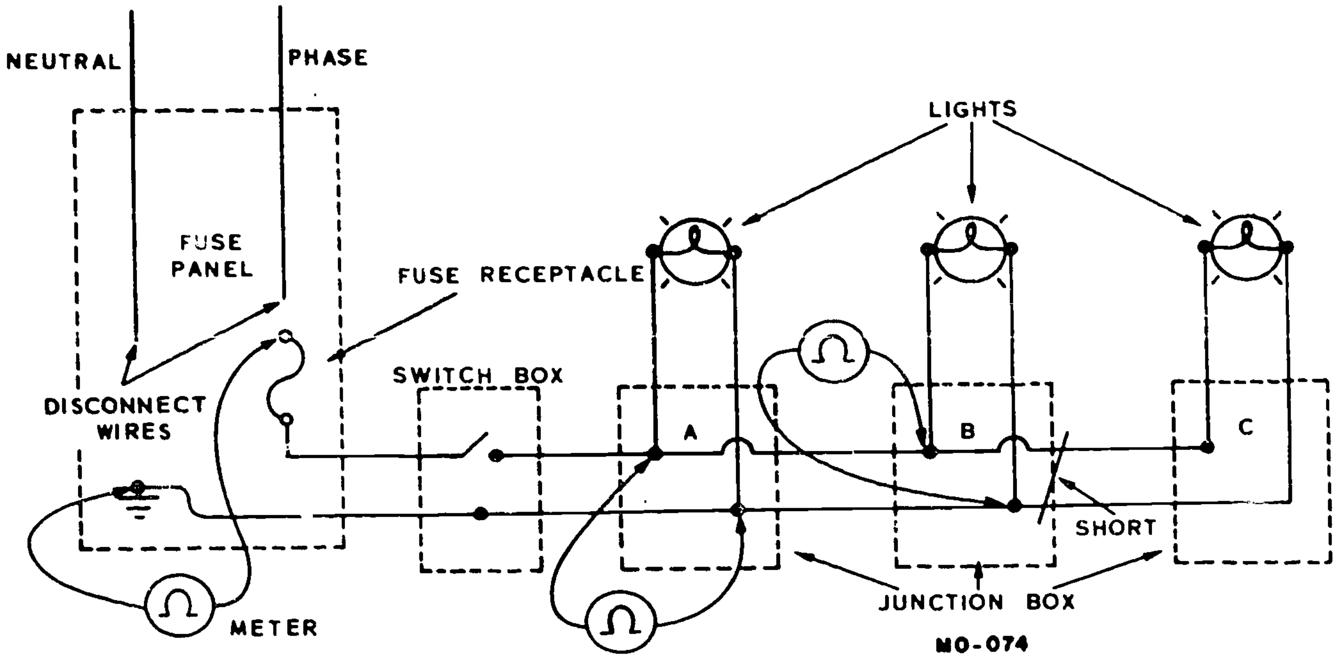



Figure 9–7. Faulty lighting circuit.

6. When using an ohmmeter to check an open circuit, what does a high-resistance or a low-resistance reading mean?

**273. Specify troubleshooting procedures for shorts and grounds.**

**Checking for Shorts and Grounds.** A short circuit exists when there is a direct connection between two wires or conductors of different potentials. If the trouble is not found by a visual inspection, you must isolate it step by step. First, disconnect all the equipment in the circuit and install a new fuse or place the circuit breaker to the ON position. If the short is clear, then the trouble will be found in the equipment. However, if the short circuit does not clear and the fuse burns out again or the circuit breaker trips, then the trouble is in the wiring.

To find the short in the electrical wiring, you first disconnect the wires at both ends of the circuit and test each wire with an ohmmeter. However, for your safety, before you begin testing with the instrument, be sure that the circuit you are about to test is deenergized.

If there is a short between the wires, a low-resistance reading will appear on the ohmmeter. If no short exists between the wires, a high-resistance reading will appear on the ohmmeter. You should continue this procedure until the short is found.

Let's assume that a light circuit is faulty. Using figure 9-7 as an example you see a circuit with three lights controlled by a switch with a short at the junction box of the middle lamp. Disconnect the wires at the fuse panel to isolate the circuit and to prevent feedback from other circuits.

Connect one lead of the ohmmeter to the neutral and the other to the wire you have just disconnected. With the switch open, the ohmmeter will read infinity. Closing the switch will cause the ohmmeter to read continuity, showing that the short is beyond the switch. You can now proceed to the nearest junction box and test at the first light. Remove all light bulbs from the circuit.

Disconnect point A and connect the ohmmeter between the neutral and the wire leading to the first lamp. You will read infinity. Remember, infinity means that the circuit is good and continuity means a short. Now, connect the ohmmeter between the neutral and the lead going to the middle lamp. The reading will show continuity, indicating the short is beyond point A. You should leave point A open at this time and continue on to the middle lamp.

Disconnect point B and take the same readings that you took at the first light. From these tests, you can determine that the circuit between the first and middle lamp is alright (infinity reading), and the trouble must be between the second and third lamp. By checking closely at the middle junction box, you can probably see charred or frayed wires indicating the problem. You may need to continue your check to point C. Use the same procedure as with the other lamp, and find the trouble between points A and C.

**Exercises (273):**

1. When does a short exist?

2. When using an ohmmeter to check for a short, what does infinity reading mean after checking across two points?

3. What is indicated if, after you disconnect all equipment and install a new fuse, the fuse does not burn out?

4. During a visual inspection, what might be an indication of shorted wires?

# ANSWERS FOR EXERCISES

CHAPTER 1

**Reference:**

200 − 1. Elements are known as the building blocks of nature.
200 − 2. Matter is composed of very small units called molecules, which are made up of atoms, which in turn are made up of particles called protons, neutrons and electrons.
200 − 3. To water flowing through a pipe.
200 − 4. Water is composed of two distinct elements: two parts of the element hydrogen ($H_2$) and one part of the element oxygen (O), expressed $H_2O$.
200 − 5. Compounds can be separated only by chemical means, and a mixture can be separated by physical means.
200 − 6. A molecule.
200 − 7. Atoms.
200 − 8. Electrons moving or flowing through a conductor.

201 − 1. Voltage is electrical pressure.
201 − 2. Heat, magnetism, chemical action, and physical force.
201 − 3. Magnetism and heat.
201 − 4. By the cross-sectional area, the length, and temperature.
201 − 5. The ohm.

202 − 1. A natural magnet is a black mineral ore called lodestone or magnetite exhibiting magnetic properties. An artificial magnet is made of iron or steel magnetized by induction from some exterior object.
202 − 2. The lines connecting the direction of the field around a magnet from pole to pole are called lines of force.
202 − 3. It has an unstable physical structure and a low magnetic strength.
202 − 4. Hard steel or other substance that has the same characteristics. Hard steel will hold its magnetism for a long period of time.
202 − 5. In a north-south direction, aligning itself with the earth's magnetic field.
202 − 6. The field of stress interacts, causing repulsion or attraction, depending upon the polarity of the poles.

203 − 1. T.
203 − 2. F. All forces produced by magnetic circuits are called magnetomotive force. Electromotive force is the pressure needed to produce a flow of electrons.
203 − 3. T.
203 − 4. F. The lines of force are concentrated within the loop. The lines inside the loop combine as they come together.
203 − 5. T.

204 − 1. Electrons moving in one direction through a conductor.
204 − 2. Electrons moving back and forth through a conductor at a specific interval.

205 − 1. The relationship applies to any circuit or part of a circuit; the current in amperes is equal to the EMF in volts divided by resistance in ohms.

205 − 2.

a. $$R = \frac{E}{I}, R = \frac{90}{30}, R = 3 \text{ ohms}.$$

b. $E = I \times R, E = 2 \times (7 + 5), E = 2 \times 12, E = 24$ volts

c. $$I = \frac{E}{R}, I = \frac{24}{10 + 8 + 6}, I = \frac{24}{24}, I = 1 \text{ amp}.$$

205 − 3. In a series circuit, the relationship is as follows:

a. The total resistance is the sum of the individual resistors.
b. The same current flows in each part of the circuit.
c. The applied voltage will divide among the resistors according to their resistance.

206 − 1. The first step should be to reduce the two parallel resistors B and C to an equivalent single resistance.
206 − 2. In a parallel circuit, the total current equals the sum of the current in the branches.
206 − 3. The voltage drop would be computed by using the formula $E_s = I_T \times R_S$, thus $3 \times 10 = 30$ volts drop.
206 − 4. A series-parallel circuit should be reduced to an equivalent, simplified circuit. Each group of parallel resistors is first replaced by its equivalent single resistance, and the entire circuit is then treated as a series circuit.

207 − 1.
(1) d.
(2) b.
(3) a.
(4) c.
207 − 2. The power is computed with the formula $P = I^2R$.
207 − 3. 120 watts.

208 − 1. From negative to positive.
208 − 2. The term "hertz" has been adopted in recognition of Heinrich Rudolph Hertz, a German physicist.
208 − 3.
(1) i.
(2) a.
(3) k.
(4) b.
(5) e.
(6) h.
(7) d.
(8) f.
(9) c.
(10) c.
(11) j.
(12) l.

209 − 1. The current flow in a circuit containing resistance only is the same, regardless of whether the applied voltage is AC or DC.
209 − 2.
(1) c.
(2) a.
(3) b.
(4) e.
(5) d.

210 − 1. When the circuit consists of pure resistance.
210 − 2. When the current and voltage are out of phase due to reactance in the circuit.
210 − 3.

$$\text{Power factor} = \frac{\text{true power}}{\text{apparent power}}.$$

210 − 4. Pf = 90.47 or 90.5 percent.
210 − 5. Wattless power or reactive power expressed in VARs.

211 − 1. The function of a generator is to convert mechanical energy into electrical energy. This is done by the rotating field through the use of electromagnetic induction.
211 − 2. The correct statements are a, c, d, and f.

212 − 1. Single and three-phase.
212 − 2. By the principle of either moving conductors across a magnetic field or moving a magnetic field across the conductors.
212 − 3. Delta or wye.
212 − 4. The first half revolution of the rotor produces a voltage in one direction and completes the first half of the cycle; the second

half revolution produces a voltage in the opposite direction and completes the last half of the cycle.
212 − 5. An exciter supplies the DC voltage.
212 − 6. 120°.

213 − 1. The primary cell can't be recharged; the secondary cell can.
213 − 2. The negative plate is spongy lead and the positive plate is lead peroxide.
213 − 3. Sulfuric acid and water solution.
213 − 4. Potassium hydroxide and distilled water.

214 − 1. 20 VAC.
214 − 2. Instrument transformers.
214 − 3. Step it up.
214 − 4. Buildup and collapse of the current.
214 − 5. Primary winding, secondary winding, and an iron core.
214 − 6. It may be center-tapped.

215 − 1. Transistors and vacuum tubes both conduct current in one direction easier than in the other direction.
215 − 2. There are three leads on a normal transistor. The center lead will always be the base lead.
215 − 3. When a high voltage gain is desired, the transistor is connected as a common base circuit.

216 − 1. The ordinary diode is a two-element, unilateral conductor and designed for current to flow through it in only one direction.
216 − 2. By an arrow printed on the side of the diode.
216 − 3. An SCR will conduct only if a voltage or current pulse is applied to the gate terminal. It will continue to conduct until its input voltage drops to zero or changes polarity, or its output voltage changes polarity.
216 − 4. In series.
216 − 5. A Zener diode conducts current in a forward direction at a very low voltage. In the reverse direction no current will flow until the voltage impressed across it is equal to the Zener voltage.

217 − 1. T.
217 − 2. F. WHen the core is near saturation it only requires a small change in the bias current to cause a large change in the load.
217 − 3. F. If the AC coil is the bias winding, then the saturation would be impossible to control due to the AC current changing directions.
217 − 4. T.
217 − 5. F. If the core is saturated, then the bias or control windings will not change the load current at all. To vary the amplifier you need some room for adjustment.

## CHAPTER 2

218 − 1.
(1) h.
(2) b.
(3) a.
(4) h.
(5) c.
(6) e.
(7) d.
(8) f.
(9) c.
(10) b.
(11) h.
(12) b.
(13) g.
(14) a.

219 − 1.
(1) c.
(2) a.
(3) g.
(4) d.
(5) f.
(6) e.
(7) g.
(8) a.
(9) c.
(10) d.
(11) b.
(12) d.
(13) f.
(14) b.
(15) b.
(16) c.
(17) d.
(18) f.
(19) g.
(20) g.
(21) e.
(22) d.
(23) b.

219 − 2.
(1) d.
(2) e.
(3) a.
(4) b.
(5) c.

220 − 1. Fish tape. It is used to pull winch line or rope through first; then the winch line or rope is used to pull the conductors.
220 − 2. Folding rule.
220 − 3. By extending the metal slide at one end.
220 − 4. To measure the diameter of a wire to check the size.
220 − 5. To eliminate the danger of electric shock.
220 − 6. Reamer.
220 − 7. Make sure the size of wire being stripped is not larger than the slot. If you don't, the wire may be nicked or cut.

221 − 1. Electric and nonelectric.
221 − 2. Propane.
221 − 3. Soldering copper.
221 − 4. In watts.
221 − 5. To absorb heat and protect components.

222 − 1. Lead and tin.
222 − 2. The solder contains 60 percent lead and 40 percent tin.
222 − 3. Rosin flux.
222 − 4. It must be tinned.
222 − 5. Clean with a rosin flux.
222 − 6. From under the splice or joint.
222 − 7. Make sure enough heat is used.

223 − 1. T.
223 − 2. F. By a key-type gear check.
223 − 3. T.
223 − 4. F. The spade bit does not have a screw tip; therefore, pressure must be applied.
223 − 5. F. You must reduce the pressure or the bit will splinter the wood.
223 − 6. T.
223 − 7. T.
223 − 8. T.
223 − 9. F. Several types of blades are made for the saber saw to cut different types of material.
223 − 10. T.

223 - 11. F. Always apply steady, even pressure and hold the base plate firmly against the work.

## CHAPTER 3

224 - 1. A thin rod of hard or soft drawn metal that conducts easily, such as copper or aluminum.
224 - 2. A bare or insulated wire or group of wires not insulated from each other, which is suitable for carrying current.
224 - 3. A solid conductor is a single wire; a stranded conductor is a group of single wires twisted together.
224 - 4. Copper.
224 - 5. No. 40, the smallest, to No. 4/0, the largest.
224 - 6. No. 2 AWG.
224 - 7 They are sized according to cross-sectional area and numbered, according to circular mils.
224 - ` For flexibility.
224 - 9.
a. TA-Thermoplastic and asbestos.
b. RH-Heat-resistant rubber.
c. THW-Moisture and heat-resistant thermoplastic.
224 - 10. Conductors in conduit will not get rid of heat as fast as those in free air.

225 - 1. To reduce the possibility of fire; to provide physical protection for wire terminals, splices, and electrical devices; and to protect people from accident shock, burns, or possible electrocution.
225 - 2. Outlet boxes and junction boxes.
225 - 3. An outlet box is used to mount a switch, receptacle outlet, or lighting fixture, while a junction box is used to inclose connections or splices between conductors.
225 - 4.
a. T.
b. T.
c. T.
d. F.
e. F.
225 - 5. Handy.
225 - 6. Metal and insulating material.
225 - 7. Boxes are galvanized, enameled, or coated with other corrosion-resistant material.
225 - 8. With nonmetallic wiring methods, such as nonmetallic sheathed cable or rigid nonmetallic conduit.
225 - 9. A prepunched disk that can be knocked out easily so that conduit or cable connectors can be installed.
225 - 10. A prepunched slotted piece, that can be twisted out with a screwdriver. They are punched in boxes with built-in cable clamps.
225 - 11.
(1) e.
(2) d.
(3) e.
(4) b.
(5) b.
(6) c.
(7) d.
(8) e.
225 - 12. By use of a fixture stud.
225 - 13. Conduit can be connected to the sides of the boxes as well as to the back.
225 - 14. A pull box is used to allow conductors to be pulled through conduit to an intermediate point in the circuit and then to the end point without having to be cut and spliced.
225 - 15. A square box.
225 - 16. Ganging means to remove one side from two device boxes and then fasten them together by means of the side retaining screws to form a large box to mount two devices side by side.
225 - 17. They may be used as junction boxes or for switches or receptacles in concealed wiring.
225 - 18. A round box.
225 - 19. An extension ring looks similar to a box without a closed back. It has a narrow flange that provides a seat for mounting the extension to a box.
225 - 20. To increase box capacity, to bring the edge of a box out flush with the wall surface when a box has been mounted too deep, and to extend the edge of an old box beyond the surface of a wall to permit the addition of surface wiring.
225 - 21. By using rings designed to extend existing boxes flush to the new wall. They are held in place by long screws run through the devices and rings, and screwed into the original box mounting holes.

226 - 1. T.
226 - 2. F.
226 - 3. T.
226 - 4. T.
226 - 5. T.
226 - 6. T.
226 - 7. T.
226 - 8. T.
226 - 9. F.

227 - 1.
(1) a.
(2) h.
(3) b.
(4) c.
(5) d.
(6) e.
(7) i.
(8) j.
(9) f.
(10) g.

228 - 1. To connect and disconnect electrical circuits or components from the power source.
228 - 2. Two three-way switches.
228 - 3. Two three-way switches and one or more 4-way switches, depending on the number of switching locations required.
228 - 4. Three.
228 - 5. In a switchbox with the toggle pointed up when the switch is on and covered with a switchplate.
228 - 6. Switches are rated according to voltage and amperage capacities.
228 - 7. Four.
228 - 8. All conductors at the same time.
228 - 9. SWD.
228 - 10. 6 1/2 feet.

229 - 1. A receptacle is a contact device installed at the outlet box for connecting and disconnecting appliances, tools, etc.
229 - 2. Attachment plug.
229 - 3. A heavy-duty receptacle is ordered for a specific voltage, amperage, and number of contact pins required.
229 - 4.
(1) d.
(2) c.
(3) a.
(4) e.
(5) e.

230 - 1. Light fixtures are classified according to the way they distribute light.
230 - 2. Direct, semidirect, general diffuse, semi-indirect, and indirect.
230 - 3. 10-40 percent.
230 - 4. 10-40 percent.
230 - 5. Indirect.
130 - 6. Indirect.
231 - 1. The incandescent lamp.
231 - 2. The incandescent lamp.
231 - 3. Mogul socket.
231 - 4. The medium socket.
231 - 5. The candelabra and intermediate sockets.
231 - 6. At least an 80-watt incandescent lamp.

231 – 7. When the ballast is energized, an electrical discharge varporizes the mercury in the tube to produce ultraviolet rays. The rays activate the fluorescent chemicals on the inside of the tube causing them to glow and produce light.

232 – 1. Efforts to improve power efficiency and reduce maintenance costs.

232 – 2. Due to a negative resistance characteristic.

232 – 3. Lamp life and more light per watt.

232 – 4. One main electrode is the anode and the other electrode is the cathode. As the voltage changes polarity in the circuit, so do the electrodes change polarity.

232 – 5. 2400 hours.

232 – 6. Mercury.

232 – 7. Metal halide and high-pressure sodium.

232 – 8. Ballasts may be mounted in the fixtures, centrally located or built into the lamp envelope.

232 – 9. The type of mounting required, the type of lighting desired (diffused or bright), bulb position, installation, and adequate cooling.

232 – 10. Normally nothing; HID lamps require less power than incandescent systems.

## CHAPTER 4

233 – 1. Primarily lighting with some motor operation, fairly heavy lighting with moderate requirement for power equipment, and mostly power equipment with a small lighting load.

233 – 2. Two-wire, single-phase system.

233 – 3. A three-wire, single-phase system.

233 – 4. Three-phase, three-wire.

233 – 5. A three-phase, four-wire system.

233 – 6. Because the voltage from the third-phase conductor to the neutral is much higher than 120 volts and would burn out any lights attached to it.

233 – 7. The wild leg will be color coded orange whenever it is in the same inclosure as the neutral. The phase relationship on panelboards will always have the wild leg in the center, or "B" position.

234 – 1. The service drop consists of two, three, or four conductors, and fittings or insulators for attaching the conductors to the building. The conductors serve to bring the power to the building from the distribution system. The fittings provide insulated anchorage for the conductors.

234 – 2. 10 feet.

234 – 3. 18 feet.

234 – 4. At least 3 feet.

234 – 5. Conductors, service head, raceway, meter socket, service disconnect, overcurrent protector, panelboard, grounding electrode and conductor, and bonding jumper.

234 – 6. To bring power from the service drop into the building to a panelboard.

234 – 7. To protect the conductors from physical and weather damage.

234 – 8. The service head provides an entrance for conductors into a raceway and prevents rain from entering the raceway. Bushings in the conductor-entry holes reduce insulation abrasion.

234 – 9. The end of the service entrance cable is bent to form a gooseneck to keep rain out and the gooseneck is taped and painted or taped with self- sealing, weather-resistant thermoplastic.

234 – 10. A meter socket is put in the service entrance in which a wattmeter is installed to record the power used.

234 – 11. The service entrance disconnects consist of a combination of switches and overcurrent protective devices. The switches are connected so that the entire interior wiring can be disconnected from the exterior power supply, and the overcurrent devices protect the service conductors.

234 – 12. Knife-blade switch, fuse block, disconnect, multipole- breaker assembly and single-pole switches or circuit breakers (not to exceed six).

234 – 13. Manual opening.

234 – 14. At a panelboard.

234 – 15. It must be attached so it can be disconnected, such as with pressure connectors.

234 – 16. The building water supply.

234 – 17. Within an electrically continuous protective metal covering.

234 – 18. They are bonded together electrically.

235 – 1. The size of the service-entrance conductors.

235 – 2. On the number of square feet, and the buildings intended use.

235 – 3. 100 amperes.

235 – 4. *The National Electrical Code*.

235 – 5. The service mast is made from a continuous length of conduit. It generally passes through the roof and is brought down between the wall studs or outside the wall. It must be firmly anchored with pipe clamps or other approved fittings and have roof flashing with neoprene seal installed to prevent water leakage. A weatherhead is installed at the top of the mast and fittings are attached to the bottom for mounting a meter base and/or the service disconnect.

235 – 6. The service disconnect is generally a surface- mount unit installed on the inside wall directly behind the service entrance conduit. The conduit may enter the box from the back or top. Remove the proper knockout plug for entry of the conduit. The box is secured to the wall by screws or anchors. A grounding bushing is installed on the end of the conduit after it is attached to the box.

235 – 7. When the service entrance includes a meter.

235 – 8. 24 inches.

235 – 9. To prevent water from running down the service conductors into the weatherhead when it rains.

235 – 10. Special connectors must be used to splice aluminum and copper conductors. These connectors prevent electrolytic corrosion from occurring between the copper and aluminum.

235 – 11. By pressure-type terminals.

235 – 12. A service-entrance cable has the insulated conductors wrapped with the stranded neutral conductor, which provides some protection against physical damage and adds some stiffness. A moisture-seal tape is applied over the neutral conductor, and the entire cable is covered with a flame-retardant and moisture-resistant cover.

235 – 13. The end of the service-entrance cable is formed into a gooseneck which is then taped and painted or toped with a self-sealing, weather-resistant thermoplastic.

235 – 14. A cable clamp must be applied within 12 inches of the weatherhead, gooseneck, or connection to a raceway and added clamps are required at points not more than 4 1/2 feet apart.

235 – 15. A hole appropriate to the cable size is drilled through the wall. If the grounding electrode conductor comes out the entry hole, added space must be allowed. When the cable is inserted through the wall, a wallplate with either a soft rubber gasket or nonhardening sealing compound is screwed to the wall.

236 – 1. Service lateral.

236 – 2. To an overhead distribution system, to an underground secondary main, or to a transformer connected to an underground main.

236 – 3. It may be installed in rigid conduit, either metal or nonmetallic, or with underground service entrance cable.

236 – 4. When the meter is to be part of the system, the wiring method is changed, or multiple disconnects are used.

236 – 5. At the point of entry to the building.

236 – 6. At least 18 inches.

236 – 7. The cable must be protected by an approved entrance or raceway from the point of entrance to below the ground line and beyond the walls of the building.

237 – 1. One.

237 – 2. Lighting and appliance panels, power panels, and feeder panels.

237 – 3. A lighting and appliance panelboard is one that has more than 10 percent of its overcurrent devices rated at 30 amperes or less and has provisions for neutral connections.

237 – 4. A power panelboard is used to provide power to electrical equipment, normally at 240/480 volts.

237 – 5. Feeder panelbo[illegible]

237 – 6. This allows branch circuits in the areas where they are most useful, with an overall savings in material.

237 – 7. It must show the voltage, current rating, number of phases, and the manufacturer's name or trademark.

237 – 8. It must be protected on the supply side by not more than two

main circuit breakers on two sets of main fuses having a combined rating no greater than that of the panelboard.

237 – 9. A terminal bar must be provided for attachment of feeder and branch circuit equipment-grounding conductors. This terminal bar must also be bonded to the cabinet.

237 – 10. It should have an orange outer finish or be tagged clearly.

237 – 11. On the ampacity of the panel's bus bars.

237 – 12. Three bus bars.

237 – 13. A dead front fuse panel is one that has no live parts exposed when the door is open. The cover must be removed to gain access to the interior parts.

237 – 14. Plug fuse, cartridge fuse, and knife-blade fuse.

237 – 15. An Edison fuse panel can be installed only when it is modified by inserting adapters in the fuse holders to accept type S plug fuses.

237 – 16. When an overload occurs and trips the circuit breaker, the breaker can be reset to restore the circuit without having to remove and replace it.

237 – 17. Circuit breakers can be reset after being tripped, while a blown fuse must be removed and replaced. Circuit breakers can also be used as a switch to shut off the circuit.

238 – 1. The panelboard to be installed is determined by the size of the building and the equipment to be used in it.

238 – 2. To provide for future expansion.

238 – 3. Exposed wiring uses a surface-mounted cabinet while concealed wiring needs a flush-mounted cabinet.

238 – 4. A 1/4-inch airspace must be provided.

238 – 5. The cabinet may be recessed in the wall with the front edge up to 1/4 inch from the finished surface. The cabinet is attached to the wall with hollow wall fasteners or masonary anchors.

238 – 6. The hole must be closed with a plug or plate to provide protection similar to that provided by the original cabinet walls.

238 – 7. By use of insulated busings on the end of the conduit.

238 – 8. Conductor ends should be cut at least long enough to allow any conductor to be connected at any point in the cabinet.

238 – 9. By use of a bonding jumper between the bar and the cabinet or by turning a screw through the bar into the cabinet.

238 – 10. When the panelboard is used as service equipment.

238 – 11. They are looped around a screw-type terminal (terminal loop).

238 – 12. A terminal lug.

238 – 13. Large conductors, neutral conductors, and equipment grounding conductors.

238 – 14. Conductors are run beside the panelboard and then looped back 180° before being connected to their fuses or circuit breakers.

238 – 15. The breaker.

238 – 16. The arrangement of the bus bars in the panelboard, whether circuits are 240 volts or 120 volts, and the need to balance the load.

238 – 17. Split bus.

238 – 18. Any two adjacent 120-volt circuits being connected to different phase conductor(s).

238 – 19. Load balancing is the process of equalizing the load on the phase conductors.

238 – 20. To prevent voltage drop from overloading one side of the incoming service and to prevent the possibility of overloading the neutral.

238 – 21. The neutral load is the difference of A phase and B phase or 36 amperes.

238 – 22. The A phase amperes equals 75 ± 15 amperes.

239 – 1. Edison base and type S.

239 – 2. Edison-base plug fuses cannot exceed 30 amperes at 125 volts and can be used as replacements only.

239 – 3. Type S fuses are rated from 0–15 amperes, 16–20 amperes, and 21–30 amperes.

239 – 4. 60 amperes.

239 – 5. It is too large for the fuse clips.

239 – 6. The fuse.

239 – 7. It contains a bimetallic strip that expands and moves when heated. Current flow causes heat when an overload occurs. The heat developed expands the bimetallic strip until it trips the latch, opening the contact points, thereby interrupting the circuit.

239 – 8. By use of an electromagnet.

239 – 9. It opens the circuit instantaneously when there is an excess of current flow.

239 – 10 A GFCI (ground fault circuit interrupter) is used as extra protection on circuits where the potential of having a ground though the user is higher.

239 – 11. All 120-volt, single-phase, 15 and 20-ampere receptacles in bathrooms, garages, and outdoors.

240 – 1. The purpose is to reduce the electrical potential to zero, thereby reducing the probability of fire or electrical shock.

240 – 2. System and equipment grounding.

240 – 3. The high voltage on the system could break down the insulation and cause a fire or remain on the system line, producing a serious shock hazard.

240 – 4. Grounding conductor size is based on the size of the service entrance conductors.

240 – 5. No. 8.

240 – 6. Noncurrent carrying metal conduit or other raceways, outlet boxes, switch and panelboard inclosures, and electrical equipment with exposed metal parts.

240 – 7. To reduce the possibility of shock or injury to people if a live conductor contacts noncurrent-carrying metal parts of an electrical system.

240 – 8. Bonding jumpers.

240 – 9. Bonding jumper size for equipment grounding is based on the size of the equipment-grounding conductors.

241 – 1. An underground water pipe that has direct contact with the earth.

241 – 2. Bonding jumpers must be installed.

241 – 3. The water pipe must be supplemented with at least one added electrode in the form of another piping system, grounded metal frame of the building, reinforcing bar in the foundation, buried copper conductor, or a made electrode. The two electrodes must be connected together electrically to equalize ground potential.

241 – 4. One or more of the following things can be used as a grounding electrode: metal underground gas piping system, if its use is permitted by the gas supplier; metal underground system or structures such as a heating system or tank; or a made electrode.

241 – 5. Galvanized steel pipe or conduit at least 3/4 inch in diameter. Steel rods 5/8 inch in diameter or nonferrous rods 1/2 inch in diameter. Pipe and rod electrodes must be 8 feet or longer in length. Metal plates with a minimum of 2 square feet exposed to earth. Steel plates need to be 1/4 inch thick and nonferrous plates at least .06 inch thick.

241 – 6. The electrode will be buried in a trench dug to below permanent moisture level and must be at least 8 feet long.

241 – 7. They may be from copper or other noncorrosive metal.

241 – 8. Resistance.

241 – 9. A fairly accurate check of resistance can be made with an ohmmeter connected between the electrodes so a reading of the resistance can be taken. When only a single made electrode is to be checked, drive a second ground 6 feet from the made electrode and take an ohmmeter reading between them. The resistance between the electrodes and the earth must be 25 ohms or less.

241 – 10. One or more electrodes must be added at a distance of 6 feet or more to bring the resistance down to 25 ohms or less.

241 – 11. The grounding bus bar in the service equipment.

241 – 12. The grounding electrode conductor may be copper, aluminum, or copper-clad aluminum; resistant to corrosion; may be solid or stranded; can be insulated, covered, or bare; and must not have any joints or splices.

21 – 13. The grounding electrode conductor must have a protective covering such as conduit or cable armor if it is smaller than No. 6. A No. 6 conductor can be installed without a protective covering if it is fastened rigidly to the construction and is not subject to damage. No. 4 and larger conductors do not need protection unless subject to severe damage. The conductor must be firmly anchored to the grounding electrode, usually by a clamp assembly.

241 – 14. The covering must be bonded to the conductor whenever the break in the covering occurs.

241 – 15. A copper conductor.

241 – 16. A copper conductor.

241 – 17. That is to be electrically continuous from the equipment to the equipment-grounding bus bar and, eventually, to the grounding bus bar in the service equipment.
241 – 18. Separate conductors.
241 – 19. An equipment ground made from a black insulated conductor should be stripped bare at every accessible joint or the exposed covering should be colored green or have green colored tape or adhesive labels applied.

242 – 1. A branch circuit is one installed between the final overcurrent device and the outlets for connecting electrically operated equipment.
242 – 2. A feeder circuit is installed between the service equipment and the panelboard.
242 – 3. Branch circuits.
242 – 4. Subfeeders serve the same purpose as feeders except they deliver power from a feeder-fed panelboard to branch-circuit panelboards.
242 – 5. Feeders reduce the voltage loss in the conductors and save material and labor.
242 – 6. Circuits should be installed in order to keep troubles and hazards at a minimum consistent with existing conditions.
242 – 7. With nonmetallic cable.
242 – 8. Metal raceways, rigid nonmetallic raceways, and cable trays.
242 – 9. All the involved conductors must be put in the same raceway.

## CHAPTER 5

243 – 1. A blueprint is a set of instructions on how to construct a building. It is a reproduction of a set of working drawings.
243 – 2. The plot plan, exterior elevation, interior elevation, floor plan, and sectional or detail drawings.
243 – 3. The location of the service drop or service lateral, and where it is to be connected.
243 – 4. The exterior elevation shows views of finished exterior walls along with finished gradelines and floorlines.
243 – 5. The interior elevations show where counters, sinks, and cupboards are going to go in kitchens and bathrooms, which helps in determining where to put switches and receptacles.
243 – 6. Floor plan.
243 – 7. 16 feet.
243 – 8. (a) 4.
(b) 8.
(c) 5.
(d) 7.
(e) 13.
(f) 12.
(g) 3.
(h) 1.
(i) 2.
(j) 10.
(k) 6.
(l) 11.
(m) 9.

244 – 1. F. There are four basic types of electrical diagrams: the one-line, block, schematic, and wiring diagram.
244 – 2. T.
244 – 3. T.
244 – 4. T.
244 – 5. F. The wiring and connection diagram both show relative position of the components and all the circuit connections.
244 – 6. F. The schematic diagram is laid out so that the components are in line to make it easy to trace the operation.

245 – 1.

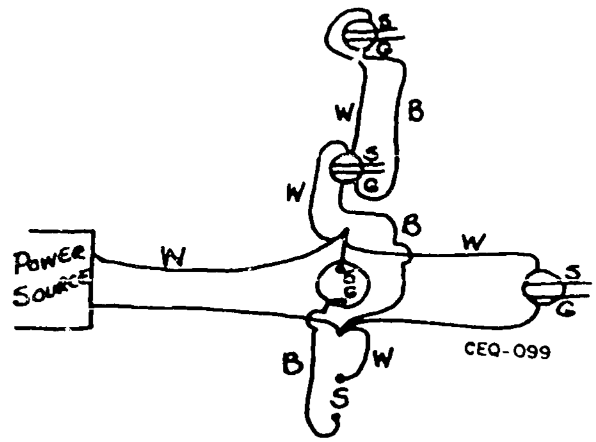



Figure 1. Answer for objective 245, exercise 1

246 – 1. 750 square feet.
246 – 2. 2250 watts.
246 – 3. Two lighting circuits.
246 – 4.
a. General lighting at two 250 watts, split on 2 circuits.
b. Laundry at 1500 watts.
c. Small appliance, 1500 watts, two each.
d. Heater 8,000 watts.
246 – 5. 14,750 watts.
246 – 6. Number 4 AWG conductors.
246 – 7. 70 amperes.

247 – 1. $20 \times 1.7A = 34A$ amp; $34A \times 120V = 4{,}080$ watts.
247 – 2. 5,300W + (25 percent of 5,300W) = 6,625 watts.
247 – 3. A 20-amp circuit breaker can carry 5,540 watts on 277 volts. The lighting load is normally continuous rated so the 20-amp circuit breaker will only be rated at 80 percent of 5,540W or 4,432W. We would use the next size circuit breaker being 25 amps.
247 – 4. One lampholder is rated 600 VA or 2.16A. 14 lampholders would draw 30.24 amps total. Multiply $30.24A \times 277V = 8{,}376$ watts.
247 – 5. 3200 divided by 120V = 26.6 amps. Figure 5-9 shows #10 TW copper conductors will carry 30 amps.

248 – 1. 4.9 amperes.
248 – 2. $4.9 \times 150$ percent or 7.35 amperes.
248 – 3. TW.
248 – 4. #12 AWG conductors are the smallest conductors allowed for general wiring.
248 – 5. Panel B-2.

249 – 1. 34 amps.
249 – 2. $35A \times 1.25 = 43.75$. Number 6 TW will carry 55 amps.
249 – 3. Number 8 TW will carry 40 amps, 3/4-inch conduit will hold four number 8 TW conductors.
249 – 4. 200 percent of FLC or 200 percent of 11A = 22 amps. The breaker should be a 20 amp inverse time breaker.
249 – 5. 70 amps.

250 – 1. 800 amps.
250 – 2. 400 MCM.
250 – 3. 48 amps (20 percent of 240 amps).
250 – 4. 500-MCM-type TW conductors, parallel in two sets of 3½ conduits, connected to a 500-amp breaker.

251 – 1.
a. 2.
b. 1.
c. 9.
d. 10.
e. 4.

f. 6.
g. 3.
h. 5.
i. 7.
j. 8.

## CHAPTER 6

252 – 1. To prevent the buildup of heat in a box.
252 – 2. By multiplying the length times the width times the depth.
252 – 3. It is triple that of a single box.
252 – 4. By consulting the table for metal boxes in the NEC.
252 – 5. You can remove one side of the box and install a space expander to replace the side.
252 – 6. You determine the free airspace requirements for each conductor by consulting the "Volume Requirements for Each Conductor" table and then get the box size by adding up the space requirements of all the installed conductors and hardware.
252 – 7. The equivalent number of conductors is four. (Two conductors, one equipment ground, and one device). No. 10 conductors require 2½-cubic- inch space each: 4 × 2½ = 10 cubic inches.
253 – 1. The side of the boxes must be removed before screws can be used to mount them.
253 – 2. Nails are placed through the holes near the bottom (or back) of the box, and are driven into the stud after the box has been positioned to project from the stud to allow for the sheetrock, using the depth markings on the box as a guide.
253 – 3. An S bracket mount.
253 – 4. Where stud spacing is less than normal.
253 – 5. A D bracket is nailed to the side of the stud, while an A bracket is nailed to both the face and the side of the stud.
253 – 6. You select the box according to the wall material to be used.
253 – 7. The bracket is placed over the face of the stud and the spurs are driven into hold the box in place while the retaining nails are driven in place.
253 – 8. The B bracket extends beyond the edge of the box enough to allow space for the device cover and screws to prevent bulging the sheetrock.
253 – 9. By using a box with an extended B bracket to provide the needed space.
253 – 10. AJ bracket.
253 – 11. The FH bracket has two barbed hooks that are driven into the face of the stud before the bracket is nailed to the side of the stud; the FA bracket is nailed only to the side of the stud.
253 – 12. When the box is being mounted next to a door, to provide for clearance between the door trim and the switch plate.
253 – 13.
a. T.
b. F.
c. F.
d. F.
e. T.
f. T.
g. F.
h. T.
253 – 14. An easy way is with a spring clip. The clip is tapped onto the open edge of the box. The box and clip are then tipped so that the upper prong slips behind the face of the stud. The lower prong of the clip is pressed back with the thumb until it slips behind the stud face and locks the box in place. They can also be attached with sheet metal screws or machine bolts and nuts.
253 – 15. Release the spring tension on the stud and move the box to the proper height.
253 – 16. Box hangers, metal straps, made metal straps, or wooden strips.
253 – 17. By installing a fixture stud or a clamp through the knockout in the bottom of the box.
253 – 18. Box hangers are adjustable so that the length is adjusted to the space as needed.
253 – 19. A piece of 1" x 4" lumber is cut to reach between the joists. It is nailed to the joists at a level that allows for the depth of the box plus the thickness of the ceiling material.
253 – 20. No specific height requirements exist. Boxes are mounted at a height that meets the needs for which they are being installed.
253 – 21. They are hard to use and may be hazardous when floors are being mopped.
253 – 22. Twelve inches from the floorline to the center of the box.
253 – 23. Marked hammer handle, rule, or notched stick.
253 – 24. A lumber crayon, carpenter's pencil, or felt-tip marker is used to show where boxes are to be mounted. The location of each box is marked with an arrowhead on the face of the stud or other framing member. The point of the arrow shows where the center box is to be mounted. The type of device to be installed can be shown with symbols, such as XX for duplex receptacle, SS for two single-pole switches, S3 for a three-way switch, or XR for a range outlet.
253 – 25. Most switches and outlet boxes in laundry and utility rooms and garages.
253 – 26. Usually when some type of wainscoting or paneling 4 feet high is to be used to finish the wall.
253 – 27. Forty-four inches.
253 – 28. Find and mark the halfway point across one dimension of the room near the center. Make a similar measurement on the other side of the center and mark the halfway point. Connect the two marks with a line. Measure the other dimension of the room and mark the center on the preceding line. This point is the location for the ceiling light.
253 – 29. Run diagonals with string from opposite corners of the room. The point of intersection is the center of the room and the place for the box.
253 – 30. Measure half the length of the room along each wall and then turn diagonals with string for each half. The intersection of the diagonals is the place for the light boxes.
253 – 31. The space between lights equals 25 divided by 3, which is 8 1/3 feet or 8 feet 4 inches. The space from the wall to the end lights is 8 feet 4 inches divided by 2, or 4 feet 2 inches.
253 – 32.
a. F.
b. T.
c. T.
d. F.
e. T.
f. F.
g. F.
h. T.
i. F.
j. T.
k. F.
l. F.
m. T.
254 – 1. Nonmetallic sheathed cable consists of two or three insulated conductors in an outer sheath of thermoplastic or treated braid. It may have an added bare or insulated conductor to be used as an equipment ground.
254 – 2. It is flame retardant and moisture resistant.
254 – 3. Conductors may be copper, aluminum, or copper-clad aluminum. Copper conductors range in size from No. 14 to No. 2 AWG and aluminum and copper-clad aluminum from No. 12 to No. 2 AWG.
254 – 4. Manufacturer's name or trademark, maximum working voltage, wire size and number of conductors, whether it has a ground, and the cable type.
254 – 5. In addition to being flame retardant and moisture resistant, type NMC cable is fungus resistant and corrosion resistant.
254 – 6. One- and two-family dwellings and other structures that are no more than three floors above grade.
254 – 7. It may be installed in either exposed or concealed work in usually dry locations (air voids in masonry block or internal tile walls) or in areas that are not subject to excessive moisture or dampness.
254 – 8. In the same places as type NM cable, plus moist, damp, and corrosive locations. These locations include outside masonry block and tile walls.
255 – 1. The National Electrical Code and the electrician's experience.
255 – 2. A straight line is the shortest distance between two points.
255 – 3. Overhead, spread out across the ceiling area.
255 – 4.
a. T.

b. F. Cable must be anchored at intervals no greater than 4½ feet.
c. F. Concealed cable is usually fastened with staples.
d. F. On every second, or on each joist, depending on distance.
e. T.
f. F. Within 6 feet.
g. F. Only cable within 7 feet of the floor or floor joists.
h. T.
i. T.
j. T.

255 – 5. To follow the surface of the building finish or be installed on running boards.
255 – 6. To the side of the stud.
255 – 7. With cable straps.
255 – 8. A round cable strap is used for a cable with three No. 8 conductors while an oval cable strap is used for one with two No. 12 conductors.
255 – 9. Not less than five times the cable's diameter.
255 – 10. Cable must be protected to at least 6 inches above floor level by rigid or intermediate metal conduit or pipe.
255 – 11. It should be protected with conduit, pipe, or guard strips.
255 – 12. Concealed wiring is wiring installed between floors and ceilings of multistory buildings, in the ceilings of finished basements, and in the walls of buildings. It is not visible or easily accessible after the building is finished.
255 – 13. Bored holes or notches.
255 – 14. From 5/8 inch to 3/4 inch in diameter.
255 – 15. Holes on an angle in studs do not provide a minimum side protection of 1 1/4 inches for the cable, thereby requiring use of metal sleeves or [illegible]es.
255 – 16. Cable is installed in metal studs through holes or slots cut, punched, or drilled at the factory or in the field. Bushings or grommets must be used to protect the cable covering unless the holes are formed so that the cable cover will not be cut or torn. A steel sleeve or plate must be used to protect the cable if it might be punctured or cut by a nail or screw.
255 – 17. The location of outlet boxes are marked, the boxes mounted in place, and the holes bored or notches cut in framing members.
255 – 18. Cable used for branch circuits is usually 12/2 with ground and comes as a 250-foot coil in a carton.
255 – 19. The end of the cable is grasped through the hole in the top of the carton and pulled out. Since the cable comes out as a spiral, it must be uncoiled before use.
255 – 20. It develops sharp kinks that damage the insulation and prevent its being pulled through bored holes.
255 – 21. Start by stripping 6 inches of the outside covering from the cable end. Remove one of the box priouts and insert the cable end through the hole and under the clamp until a quarter-inch of the cable cover extends through the clamp. Tighten the clamp to hold cable firmly in place.
255 – 22. This amount of conductor is needed to make splices or to attach devices or fixtures easily.
255 – 23. A knockout must be removed from the box and a cable connector installed to provide a means of anchoring the cable to the box.
255 – 24. Punch the hole out of the box, strip 6 inches of the cable cover, insert the cable through the box hole to expose a quarter-inch of cable cover inside the box, and anchor the cable within 8 inches of the box.
255 – 25. The cable is anchored within 12 inches of the box that the free end is attached to, and then run along the framing members and fastened at least every 4½ feet until it reaches the other box.
255 – 26. Six inches of free conductor in the box.
255 – 27. Take a look at where the holes are located and then decide where to start for the easiest installation and least waste.

256 – 1. Splices are used to connect wires together to form complete circuits and to connect or add ground wires so that all metal units in the electrical circuits are grounded.
256 – 2. It must be as strong as a continuous wire and conduct electricity as well as if it were one piece.
256 – 3. Soldered pigtails, solderless pigtails, tee splices, and crimp joints.
256 – 4. With a wire stripper.
256 – 5. It is easy to nick the wire, which may cause it to break.
256 – 6. A knife.
256 – 7. Start by cutting the insulation at an angle of about 30°. Remove the insulation about like a pencil is sharpened, being careful not to cut the wire.
256 – 8. Use the knife blade to scrape the wire until it is clean.
256 – 9.
a. I.
b. C.
c. I.
d. C.
e. C.

256 – 10. Plastic electrical tape.
256 – 11. Four.
256 – 12. It allows the tape to be applied so that a close, smooth wrap is formed. By varying the tension, the tape can be stretched to conform to angle and diameter changes to insure a snug fit.
256 – 13. The tape is applied smoothly half lapping each turn of the tape until the end of the splice is reached. At the end, the tape is folded over and then brought back toward the starting point, half lapping each wrap of the tape.
256 – 14. To make a solderless pigtail splice, remove the insulation from the ends of the wires and twist them together three turns. Finish the splice by installing a wire nut and tightening it. Properly made, the wire nut provides full insulation to the splice.
256 – 15. Tap or tee.
256 – 16.
a. T.
b. T.
c. F.
d. F.
e. F.
f. T.
g. T.

256 – 17. A splicing sleeve and a special crimping tool.
256 – 18. To splice several grounding conductors together.
256 – 19. A crimped pigtail.

257 – 1. Rigid metal conduit, intermediate metal conduit, EMT, and other raceways approved by the NEC.
257 – 2. At the service equipment.
257 – 3. By using a grounding clip or a screw that is not used for any other purpose.
257 – 4. Continuity of the equipment ground must not be broken when a receptacle is removed from the circuit.
257 – 5. Surface-mounted boxes where there is direct contact between the yoke of the receptacle and the box and any box where receptacles designed specifically to provide metal-to-metal contact between the yoke and the box are used.
257 – 6. Green hexhead.
257 – 7. Fault condition.
257 – 8. It will be bare, green, or green with yellow stripes.

258 – 1. To insure good circuit operation, prevent fire, and protect personnel.
258 – 2. Terminal loop.
258 – 3. Strip approximately 3/4 inch of insulation from the end of the conductor.
258 – 4. Needlenose or longnose pliers.
258 – 5. So that tightening of the screw will not spread the loop.
258 – 6. Circuit wires are pigtailed to the fixture wires with a wire nut.
258 – 7. Brass or dark colored screw.
258 – 8. Neutral or grounded conductor.
258 – 9. 7/8 inch, 6–32.
258 – 10. 50 pounds.
258 – 11. 8–32.
258 – 12. 1 foot.
258 – 13. Heat-resistant.
258 – 14. Between ceiling joists with special bar hangers.
258 – 15. Four feet minimum and 6 feet maximum.
258 – 16. Wood screws, toggle bolts, or lead anchors.
258 – 17. When the mounting holes of the fixture line up with the wood ceiling joists.
258 – 18. By using wood strips between the toggle and the sheetrock.
258 – 19. Lead anchors.
258 – 20. To provide a neat appearance, protect the conductors, and prevent shock.

258 – 21. One, 3/8 inch, 6–32 screw.
258 – 22. The switch must first be straightened by loosening the mounting screws, repositioning the switch, and tightening the screws. The cover plate will be straight if the switch is straight.

## CHAPTER 7

259 – 1. 18 to 32 teeth per inch.
259 – 2. So that the teeth cut when the saw is pushed forward.
259 – 3. Leave enough room to keep from hitting your hands on the vise and to allow for threading after the cut is made.
259 – 4. Tight enough to score the pipe.
259 – 5. Pipe cutters may flatten the end and leave a ridge inside that is difficult to remove.
259 – 6. Use a hacksaw to cut through one ribbon of the flex, then a reverse twist to separate the ends.
259 – 7. Ream the conduit with a reamer, rattail file, or the handles of a pair of pliers, making sure any edge or burrs are removed.
259 – 8. Rigid and intermediate metal conduit.
259 – 9. Standard conduit-cutting die with a 3/4-inch taper per foot.
259 – 10. Reverse turns keep the threads and dies clean.
259 – 11. A full thread is obtained by cutting threads until two or three extend beyond the die.
259 – 12. Up to 2-inch conduit.
259 – 13. By electric drive motors.

260 – 1. Field bends.
260 – 2. Without reducing the inside diameter of the conduit at the bend.
260 – 3. The hickey and the one shot.
260 – 4. One shot.
260 – 5. The equivalent of four quarter bends or 360° total.
260 – 6. The conduit, fittings, straps, conductors, and bends used from one opening to the next.
260 – 7. The stub.
260 – 8. The takeup.
260 – 9. The takeup is 5 inches, and the arrow of the bender is placed on the takeup mark with the lip of the bender towards the end of the stub.
260 – 10. A 90° bend is checked by placing it next to something known to be a right angle, such as a wall, and measuring from the floor to the end of the stub.
260 – 11. Two adjacent 90° bends in the same piece of conduit.
260 – 12. The second 90° of a back-to-back is made by first marking the outside-to-outside measurement on the conduit. Then subtract the takeup, place the arrow on the takeup mark, and make the bend in the same direction as you did the first, or place the star of the bender in line with the outside-to-outside mark and make the bend in the opposite direction from the first bend.
260 – 13. A box offset is two equal bends in opposite directions used to bring the conduit out from the structure to match a knockout in a box or panel.
260 – 14. Depth of the offset and amount of bend to be used.
260 – 15. Offset depth x constant multiplier = distance between bends.
260 – 16. After the marks are made, the desired amount of bend is made on the same side of each mark, using the arrow of the bender aligned with each mark.
260 – 17. Lay out the desired angle on a piece of paper or the floor and check the conduit against the angle.
260 – 18. Mark the conduit for the amount of stub needed, subtract the takeup, and make three 30° bends two inches apart.
260 – 19. Hand or electric pumps.
260 – 20. Takeup for manual benders and power benders is not the same due to different size shoes and conduit.

261 – 1. The run of conduit must be installed as a complete system before installing conductors.
261 – 2. As straight and direct as possible.
261 – 3. Install all runs at the same time.
261 – 4. 1/2 inch.
261 – 5. It must be reamed.
261 – 6. Die must have 3/4-inch taper per foot.
261 – 7. A bushing.
261 – 8. Running threads are not allowed, because they weaken the conduit at the coupling.
261 – 9. Straps are fastened onto wooden surfaces with nails or screws, and onto concrete surfaces with expansion anchors.
261 – 10. Three feet.
261 – 11. 4½ feet, 12 inches.
261 – 12. By providing an opening where conductors can be pulled or fed.

262 – 1. Lengths of conduit, size and number of boxes to go through, length of wire to leave in the boxes, and length of makeup at the distribution panel.
262 – 2. Fish tape.
262 – 3. Pair of pliers and propane torch.
262 – 4. Reheat the tape until red, allow to cool until straw colored, and then plunge it into water until cool.
262 – 5. Remove 4 to 6 inches of insulation from the ends of the conductors, thread them through the hook of the fish tape, bend them back, twist them around each other, and tape the hook and bare wires.
262 – 6. Pull from the first box and feed the panel.
262 – 7. Keep the conductors parallel and straight. Whenever possible feed downward. Apply lubricant if necessary on long runs or runs with several bends.
262 – 8. Soap, talc, soapstone or other noncorrosive substance.
262 – 9. Sidecutting pliers.

263 – 1. Circuit extensions are used to extend circuits previously installed.
263 – 2. A nonmetallic extension is an assembly of two insulated conductors in a nonmetallic jacket.
263 – 3. An underplaster extension is an extension of a circuit that can be run in EMT, IMC, rigid, flexible conduit, type AC or MI cable, and covered with plaster.
263 – 4. Surface raceway.
263 – 5. A multioutlet assembly is a type of surface of flush raceway designed to hold conductors and receptacles assembled in the field or at the
263 – 6.
a. F.
b. T.
c. F.
d. T.
e. T.
f. F.
g. T.
h. F.
i. T.
j. T.
k. T.
l. F.

## CHAPTER 8

264 – 1. Electromagnetic principle.
264 – 2. Permanent magnets are used for the galvanometer and electromagnets are used in the dynamometer.
264 – 3. Dynamometer.

265 – 1. Voltmeters and ammeters.
265 – 2. Linear scales have equal divisions across the scale; nonlinear scales have unequal divisions.
265 – 3. Divide the difference between the two numbered divisions by the number of unmarked divisions.
265 – 4. Parallax is a false reading obtained by not looking directly at the meter face.
265 – 5. The highest range.
265 – 6. To obtain a more accurate reading.

266 – 1. (1) c.
(2) b.
(3) a.
(4) b.
(5) d.
(6) b and d.

267 – 1. Place the function switch in OHMS position, set the range switch in OHMS TIMES ONE position, install the leads, and ZERO the meter.

267 – 2. Never connect the ohmmeter to a live circuit.

267 – 3. Be sure to position the function switch to any position other than OHMS TIMES. Remove the leads and place them in the cover.

267 – 4. Place the function switch on one of two positions: DC/1KΩ/V or DC/20KΩ/V. The meter leads should be connected to the meter jacks of corresponding color to prevent reverse deflection. Set the range switch to the corresponding DC voltage to be checked.

267 – 5. Place the function switch to ACV/1KΩ/V. Use the AC scale on the meter when reading. Polarity need not be observed.

267 – 6.
a. False. It is most accurate in the DC/20KΩ/V position.
b. T.
c. False. Start with the highest range and move down.
d. T.

268 – 1. False. Some may also be used for checking polarity or to determine whether the source is AC or DC.

268 – 2. False. They work only with an external source of power.

268 – 3. False. Use a lamp rated for the voltage to be tested.

268 – 4. True.

268 – 5. False. Like an ohmmeter, it should be used only on deenergized circuit.

268 – 6. True.

## CHAPTER 9

269 – 1. A planned program of routine inspections and checks along with periodic cleaning, tightening, adjusting, and lubricating, designed to keep a system in good working condition.

269 – 2. Conductor insulation, fittings and connections, and all devices.

269 – 3. Conductor insulation is checked visually and tested for resistance with a megohmmeter. Maintenance should include retaping of nicks or scrapes and replacement where repairs cannot be made.

269 – 4. Couplings, connectors, straps, and cable clamps should be checked visually and physically for looseness or separation.

269 – 5. Loose connections cause increased voltage drop, increased current flow, and excessive heat, which may cause a fire.

269 – 6. The normal operation under a specified rated load.

269 – 7. Look for the cause of the breakdown and replace or relocate equipment if necessary.

270 – 1. Loose connections, loose wires, abraded wires, and loose fittings.

270 – 2. An open circuit occurs when one or more conductors in a circuit are broken or otherwise separated.

270 – 3. Use a voltmeter to determine whether the circuit is live.

270 – 4. Solid, partial, or floating.

271 – 1. Use relatively low-voltage instruments, reducing the danger of sparking.

271 – 2. Using a voltmeter, the test will start at the power input end; using an ohmmeter, the test will start at the grounded end of the circuit.

271 – 3. Be extremely careful because of live points in the junction box.

271 – 4. (1) Ohmmeters and battery-powered test lamps;
(2) Voltmeter.

272 – 1. No. You should check the lamp with an ohmmeter for continuity. The lamp socket itself could be inoperative.

272 – 2. Take a reading between phase A and B, A and C, and B and C. Each time you read to phase C, you should get a low voltage. This is a good indication phase C is open.

272 – 3. Fuses, switches, and lamps.

272 – 4. This indicates an open in the ground wire. The lamp will not light without a completed circuit; therefore, a reading indicates voltage is available to that point but that it has not reached ground.

272 – 5. At the point where the circuit is no longer common to both lamps.

272 – 6. A high resistance means the circuit is open, and a low resistance means the circuit is good.

273 – 1. When there is a direct connection between two wires or conductors of different potentials.

273 – 2. This means the circuit is good.

273 – 3. This indicates the short is in the equipment.

273 – 4. Charred or frayed wires.



1985-631-028/20707 AUGAFS,AL(860915)1300

NOTE: 1 NEC 210-7 All receptacles 15 and 20 amp shall be grounded type.

NOTE: 2 Dashed lines on drawing are only representative of switching lights and outlets.

NOTE: 3 NEC 210-8(a-2) All 120V, 15 and 20 amp, 1Ø, dwelling-unit receptacles installed out doors shall have GFI.

NOTE 4: NEC 210-8(a-1) All 120V, 15 and 20 amp receptacles installed in bathrooms shall have GFI.

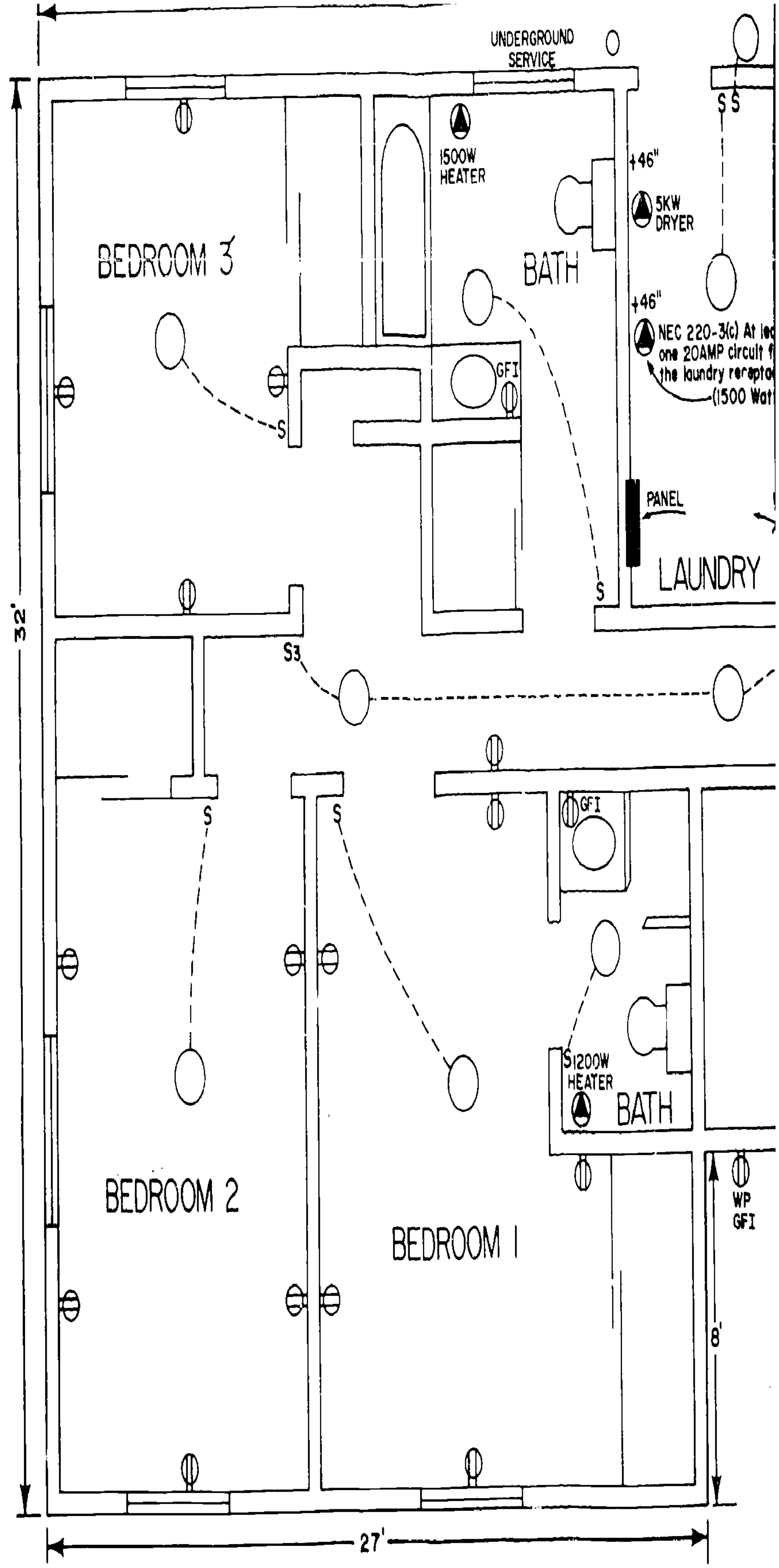
NOTE: 5 NEC 210-25(b) All rooms of general occupancy will have no space along a wall more than 6 feet from a receptacle.

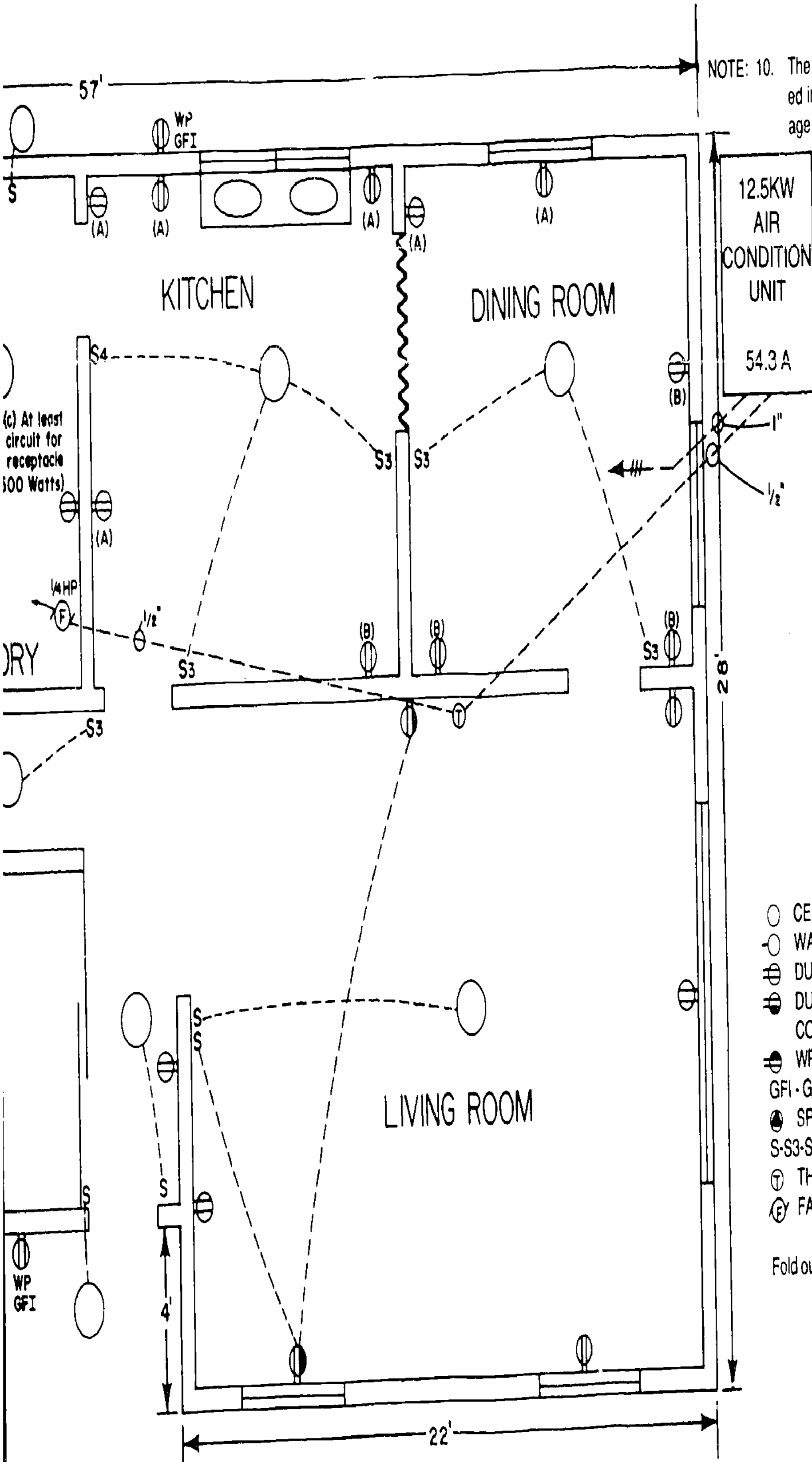
NOTE: 6 NEC 210-23 Branch circuits may be installed for specific loads (heaters in the baths).

NOTE: 7 NEC 210-26(a) At least one wall switch controlled lighting outlet shall be installed in every habitable room. Exception 1-Except the kitchen, receptacles controlled by a wall switch shall be permitted (living room).

NOTE: 8 NEC 220-3(b) Two or more 20-amp appliance circuits shall be provided in the kitchen, pantry, family room and breakfast room. The two circuits are marked A and B on the drawing. NEC 220-16(a) Feeder load for the two small appliance circuits are 3000 watts. (1500 watts each)

NOTE: 9 NEC 220-16(a)(b) Small appliance circuits and laundry loads may be included in general lighting load for feeder calculations.


UNDERGROUND SERVICE
1500W HEATER
+46"
5KW DRYER
BATH
BEDROOM 3
+46"
NEC 220-3(c) At lea
one 20AMP circuit f
the laundry recepta
(1500 Wat
GFI
PANEL
LAUNDRY
S3
GFI
S1200W HEATER
BATH
WP GFI
BEDROOM 2
BEDROOM 1
32'
8'
27'




NOTE: 10. The blower unit in the laundry is calculated in the air conditioning load as a package unit.

CALCULATIONS FOR LOAD

| | | |
|---|---|---|
| Air Conditioning | | 12,500W |
| Area = 1672 sq. ft. X 3 watts | = 5,016W | |
| Small appliance and laundry | = 4,500W | |
| Dryer | = 5,000W | |
| Space heaters (bath) omitted | ______ | |
| Total load | = 14,516W | |

| | | |
|---|---|---|
| First 10KW at 100% | 10,000W | = 10,000W |
| Over 10KW at 40% | 4,516W | = 1,806W |
| building total load | | = 24,306W |

Service Calculations
3 wire 115/230 volts
24,306 watts/230 volts = 105.6 amps.

Table 310-16, (NEC) shows #2 THW copper conductors, used for underground entrance, will carry 115 amps.

○ CEILING OUTLET
-○ WALL BRACKET
DUPLEX RECEPTACLE
DUPLEX RECEPTACLE - ONE HALF SWITCHED CONTROLLED
WP - DUPLEX RECEPTACLE - WEATHERPROOF
GFI - GROUND FAULT INDICATING
SPECIAL OUTLET
S-S3-S4 SWITCHES - SINGLE POLE, 3-WAY, 4-WAY
(T) THERMOSTAT
(F) FAN MOTOR

Fold out 1 Electrical plan, single dwelling.

# ELECTRICAL PLAN
## SCALE 1/4" = 1' - 0"



Foldout 1. Electrical diagram single dwelling.

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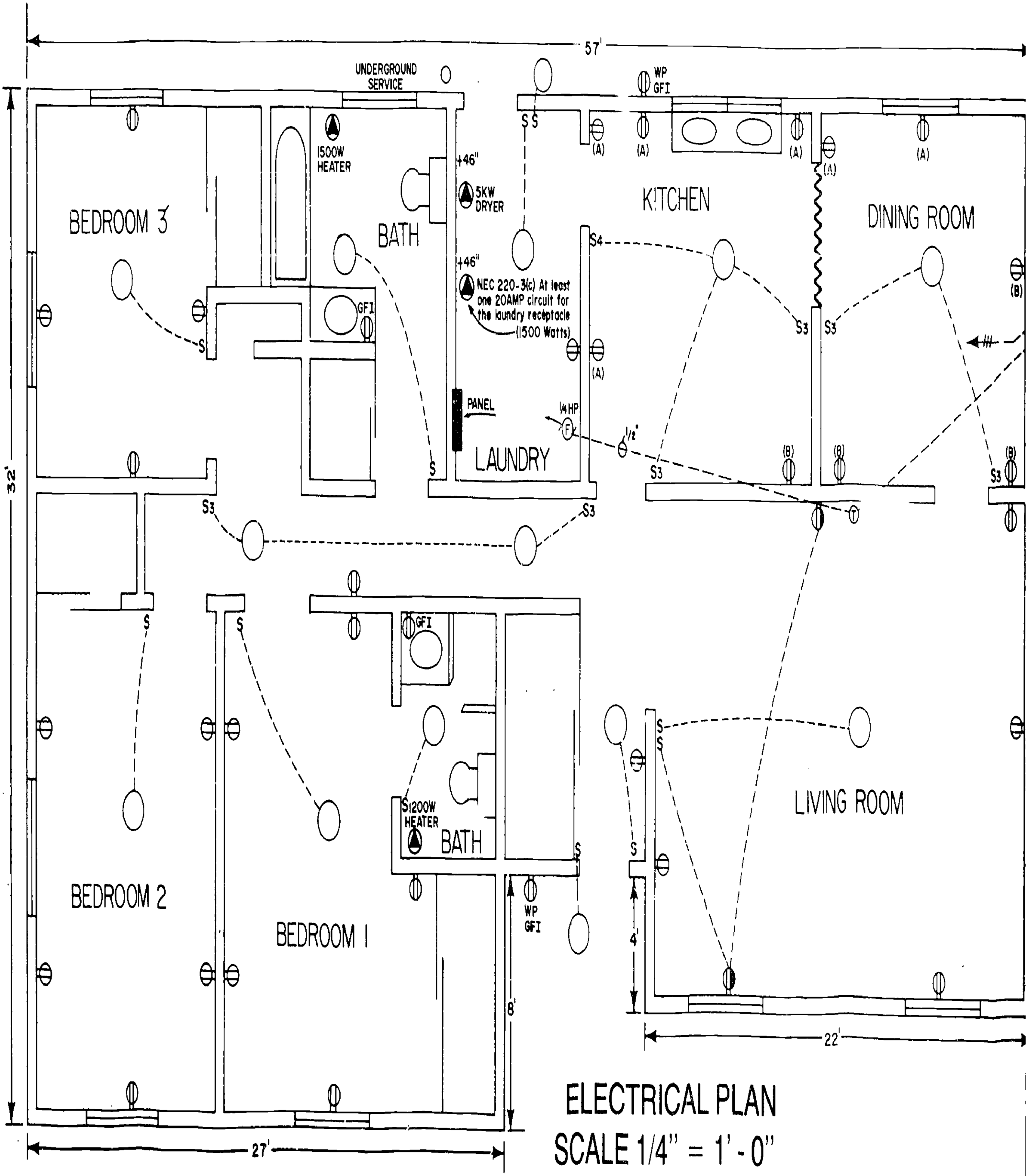


# ELECTRICAL PLAN

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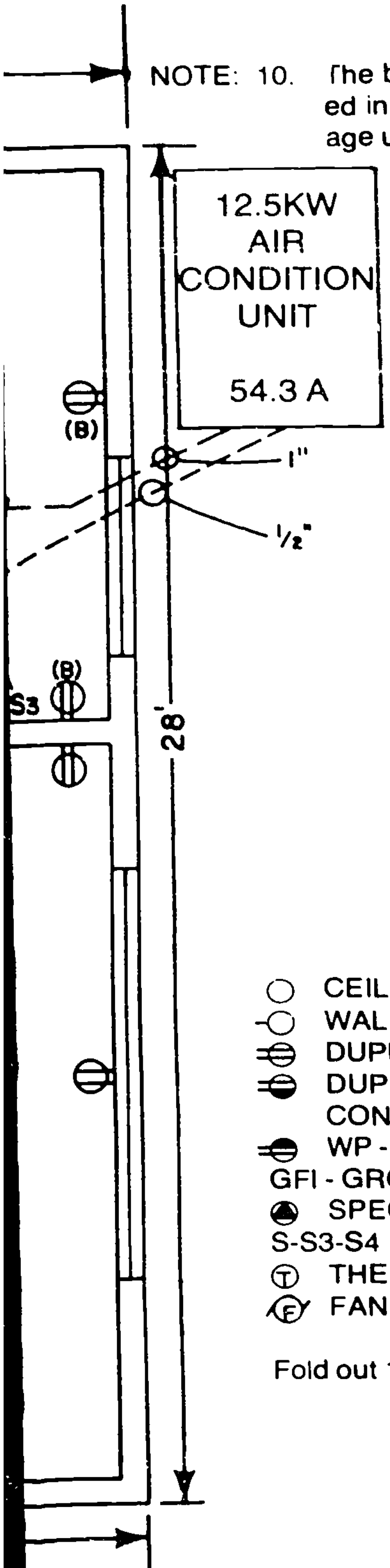


CALCULATIONS FOR LOAD

| | | | |
|---|---|---|---|
| Air Conditioning | | | 12,500W |
| Area = 1672 sq. ft. X 3 watts | = | 5,016W | |
| Small appliance and laundry | = | 4,500W | |
| Dryer | = | 5,000W | |
| Space heaters (bath) omitted | | _ | |
| Total load | = | 14,516W | |
| First 10KW at 100% | | 10,000W | = 10,000W |
| Over 10KW at 40% | | 4,516W | = 1,806W |
| building total load | | | = 24,306W |

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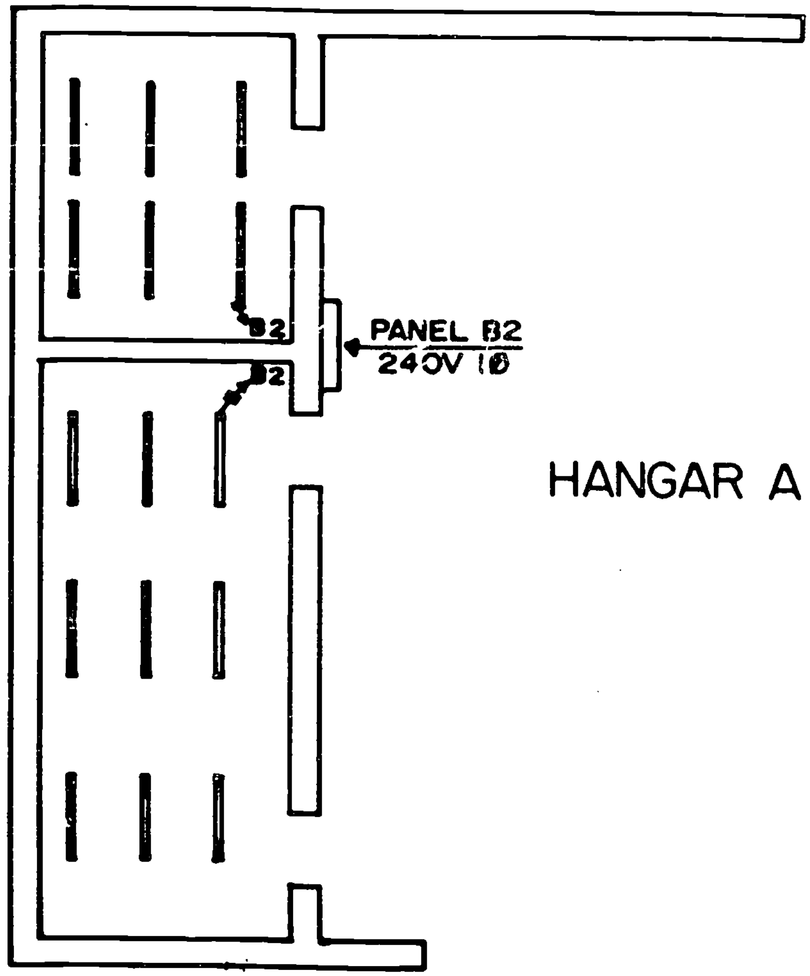
S-S3-S4 SWITCHES - SINGLE POLE, 3-WAY, 4-WAY
THERMOSTAT
FAN MOTOR

Fold out 1 Electrical plan, single dwelling.

**Foldout 1. Electrical diagram single dwelling (continued).**

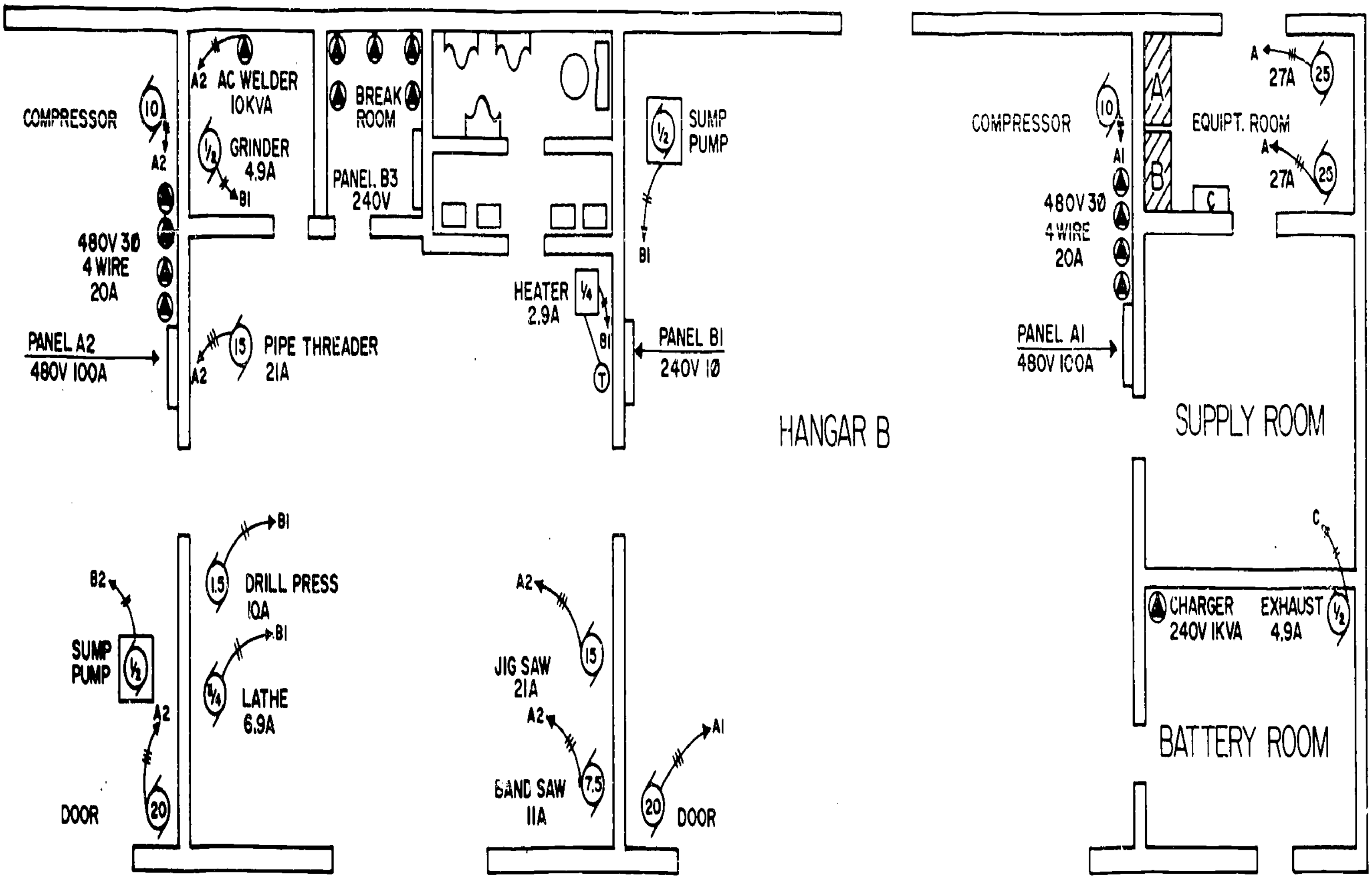



NOTE 1: Light fixtures in hangar areas shall be totally enclosed type, to prevent escape of sparks or hot metal particles. 250W, 277V mercury vapor typical, 4 rows of 4 each.

NOTE 2: Fluorescent fixtures 4 tube, 4 ft. each, 120V 2.6A typical in offices.

NOTE 3: Fluorescent fixtures 2 tube, 8 ft. each, 277 V 1.7A typical in machine shop. 4 rows, 4 fixtures end to end. Panel A2.

NOTE 4: Incandescent fixtures 150 watt 120V typical, 2 each equipment room, 4 each in latrine, 4 each in break room.




NOTE 5: Light fixtures in battery room shall be Class 1 Division 2 rated fluorescent 2 tube 4 ft. 120V, 1.3A typical. 4 each. Panel C.

NOTE 6: Break room special outlets 1Ø 3 wire 240V 20A typical. To panel B3.

NOTE 7: Latrine lighting, panel B3.

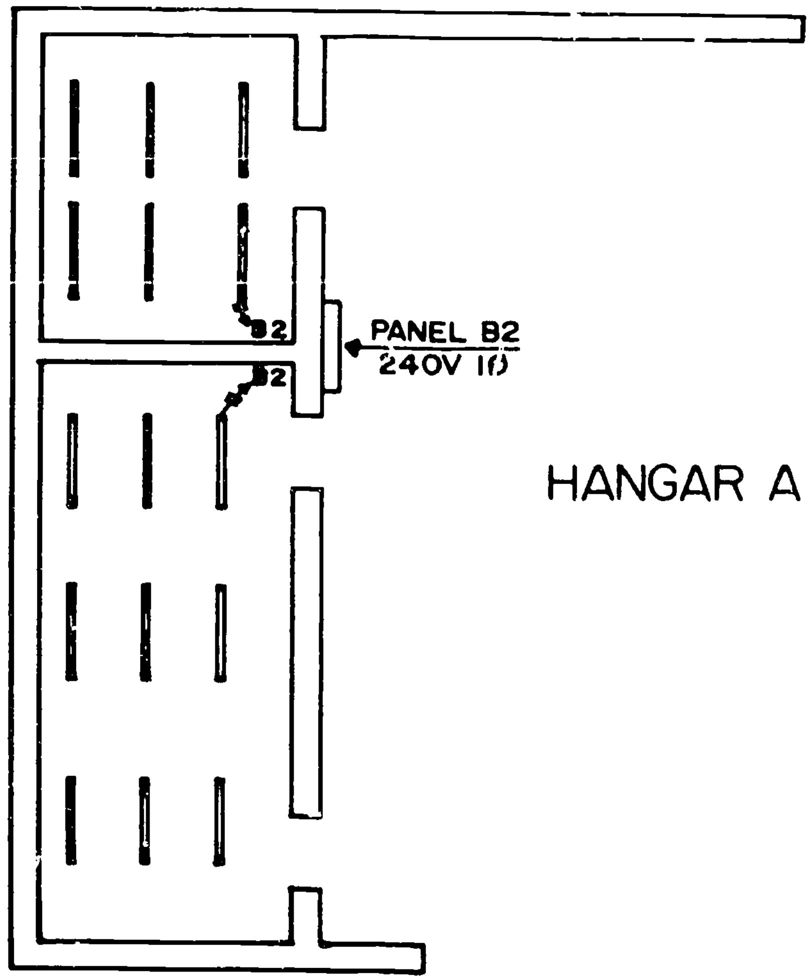
NOTE 8: Supply room and battery room feed from panel C.

SPECIFIC PURPOSE OUTLET
THERMOSTAT
FLUORESCENT LIGHT
MOTOR WITH H.P. RATING
SUB. PANEL, VOLTAGE SPECIFIED

A 277,480 VOLT Y-3Ø-4 WIRE POWER

B 120,240 VOLT 1Ø-3 WIRE POWER

Foldout 2. Electrical diagram industrial building.

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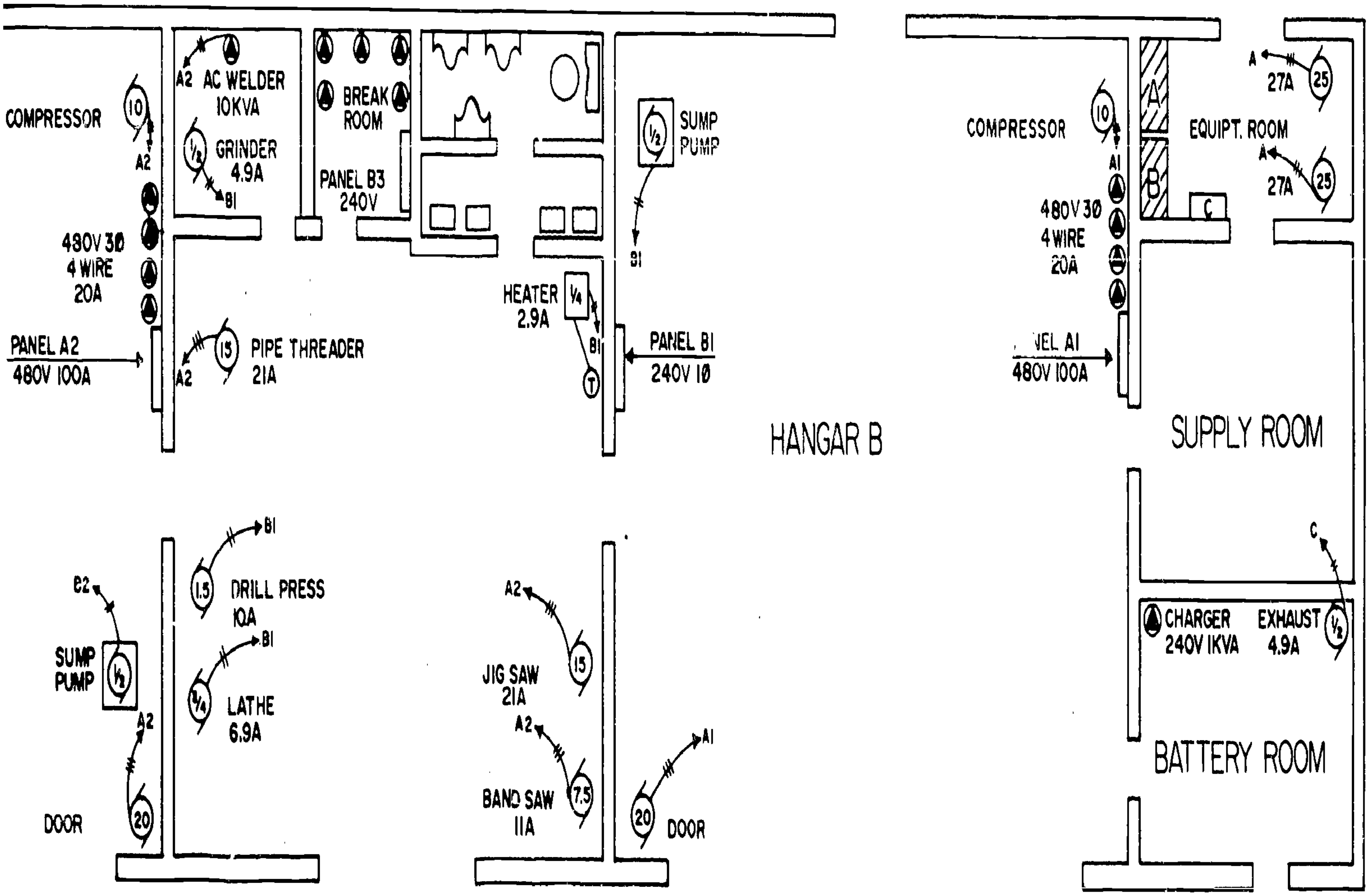


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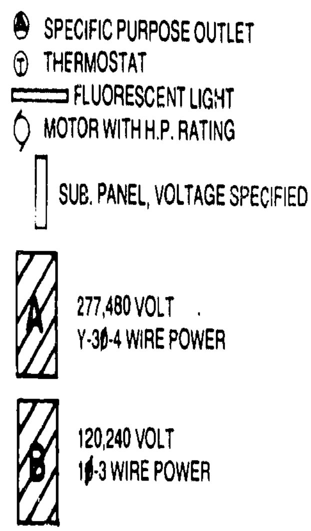


Foldout 2. Electrical diagram industrial building (continued).

S T O P - 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

54250 02 21
BASIC ELECTRICITY AND INSTALLING ELECTRICAL SYSTEMS

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet .
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you have to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If mandatorily enrolled student, process questions or comments through your unit trainer or OJT supervisor. If voluntarily enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the Learning Objective Number where the answer to that item can be located. When answering the items on the VRE, refer to the Learning Objectives indicated by these Numbers. The VRE results will be sent to you on a postcard which will list the actual VRE items you missed. Go to the VRE booklet and locate the Learning Objective Numbers for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

## MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the best answer to each question.

1. (200) Two different ways in which elements may be combined are either in

   a. atoms or compounds.
   b. atoms or molecules.
   c. compounds or mixtures.
   d. molecules or mixtures.

2. (200) According to the electron theory, atoms are composed of

   a. positive charged protons and neutrons.
   b. positive charged protons and neutral charged electrons.
   c. negative charged electrons and neutrons.
   d. negative charged electrons and positive charged protons.

3. (201) What are the three things that determine the resistance of a copper wire?

   a. Cross-sectional area, its temperature, and weight.
   b. Cross-sectional area, its weight, and length.
   c. Cross-sectional area, its temperature, and length.
   d. Its temperature, its length, and its weight.

4. (202) What material will hold its magnetism for a long period of time?

   a. Soft iron.
   b. Soft steel.
   c. Hard iron.
   d. Hard steel.

5. (203) With a current flowing through a single-loop conductor, the magnetic lines of force are concentrated

   a. around the loop.
   b. within the loop.
   c. around the conductor.
   d. at each end of the conductor.

6. (204) The automobile ignition coil circuit is a good example of

   a. pulsating (AC).
   b. pulsating (DC).
   c. alternating current.
   d. current reversing direction.

7. (205) What is the resistance of a circuit with an applied voltage of 120 volts and a current flow of 9 amperes?

   a. .13 ohms.
   b. 1.3 ohms.
   c. 13.33 ohms.
   d. 108 ohms.

8. (205) What is the current flow in a series circuit with a 20 ohm resistor, a 25 ohm resistor, and a 30 ohm resistor connected to a 25 volt power supply?

   a. .33 amperes.
   b. 7.5 amperes.
   c. 33 amperes.
   d. 75 amperes.

9. (206) The total current in a parallel circuit is equal to the

   a. current in the largest resistance.
   b. inverse sum of the applied voltage.
   c. sum of the currents in the individual branches.
   d. total voltages found in the individual branches.

10. (206) What is the joint resistance of a 5 ohm resistor and a 20 ohm resistor in parallel?

    a. 2 ohms.
    b. 2.5 ohms.
    c. 4 ohms.
    d. 5.5 ohms.

11. (206) What is the joint resistance of a " ohms resistor, a 10 ohm resistor, and a 12 ohm resistor in parallel?

    a. 2.3 ohms.
    b. 3.2 ohms.
    c. 3.9 ohms.
    d. 4.2 ohms.

12. (207) What is the unit of force in an electrical circuit called?

    a. Dyne.
    b. Joule.
    c. Volt.
    d. Wall.

13. (207) What is the current flow in amperes of a circuit with an applied voltage of 120 volts and a power consumption of 600 watts?

    a. .5 amperes.
    b. 2 amperes.
    c. 2.5 amperes.
    d. 5 amperes.

14. (207) What is the power in watts consumed by a circuit with 120 volts applied and a resistance of 12 ohms?

    a. .10 watts.
    b. 10 watts.
    c. 1200 watts.
    d. 1440 watts.

15. (208) How fast (RPM) must a 2-pole generator rotate to produce 60 Hertz?

a. 1200 rpm.
b. 1800 rpm.
c. 3600 rpm.
d. 4000 rpm.

16. (208) How is the measurement of the apparent power of an AC electrical system expressed?

a. Volt-amperes.
b. Kilovolt-amperes.
c. Millivolt-amperes.
d. Pico volt-amperes.

17. (209) What is the capacitance of a 125μ F capacitor when converted to farads?

a. .000125 f.
b. .00125 f.
c. .0125 f.
d. .125 f.

18. (210) A 110 volt AC motor records 20 in-line amperes and the in-line watt meter shows only 1936 watts being consumed. Solve for the power factor of the AC circuit.

a. 80% pf.
b. 83% pf.
c. 86% pf.
d. 88% pf.

19. (211) A generator is a device that converts

a. electrical energy to mechanical energy.
b. mechanical energy to electrical energy.
c. kinetic energy to electrical energy.
d. kinetic energy to potential energy.

20. (212) A three-phase alternator normally receives power for its rotating magnetic field from

a. a battery bank.
b. a DC generator.
c. an AC generator.
d. the alternator itself.

21. (213) The voltage of a primary cell depends only on what two factors?

a. The type of electrolyte and type of cell.
b. The type of cell and type of terminal posts.
c. The type of electrode material and type of cell.
d. The type of electrolyte and the electrode material.

22. (213) A lead-acid storage battery should have an open circuit voltage of

a. 2.0 volts.
b. 2.2 volts.
c. 2.4 volts.
d. 2.6 volts.

23. (214) What is the primary voltage of a transformer that has a secondary voltage of 240 volts and is rated 1 to 3 turns ratio?

a. 60 volts.
b. 80 volts.
c. 120 volts.
d. 360 volts.

24. (214) A step-up transformer produces a secondary voltage

a. higher and secondary current lower than the voltage and current in the primary.
b. lower and secondary current higher than the voltage and current in the primary.
c. and current higher than the voltage and current in the primary.
d. and current lower than the voltage and current in the primary.

25. (215) Reference text figure 1-46. What is the relationship of the input and output voltages of the common-emitter transistor circuit?

a. The input and output voltages are in phase.
b. The input voltage leads the output voltage 90°.
c. The output voltage leads the input voltage 90°.
d. The input and output voltage are 180° out of phase.

26. (216) How many elements are used to construct a diode that is a unilateral conductor?

a. 2 elements.
b. 3 elements.
c. 4 elements.
d. 5 elements.

27. (216) A Zener diode is processed to allow current to flow through it in a

a. forward direction only.
b. reverse direction only.
c. forward or reverse direction.
d. direction to the flow that would occur if it were a rectifier.

28. (217) What are the two coils called in a saturable reactor?

a. Load and field.
b. Core and field.
c. Bias and core.
d. Bias and load.

29. (217) If the control current is decreased on a magnetic amplifier, what effect, if any, will this have on the load current?

a. None.
b. Increase.
c. Decrease.
d. Saturation.

30. (218) What type of wrench is used on brass pipes and fittings to prevent the surface from being marred or scratched?

a. Strap wrench.
b. Pipe wrench.
c. Chain wrench.
d. Cable wrench.

31. (218) The most versatile vice is the

a. pipe vise.
b. chain vise.
c. utility vise.
d. machinist vise.

32. (219) Why is the rigid conduit cutter <u>not</u> used on thin-wall conduit?

a. It flattens the ends of thin-wall conduit.
b. It shortens thin-wall conduit about 1/4 inch.
c. It leaves burrs on the cut end of the conduit.
d. It increases the inside diameter, making it useless.

33. (219) The purpose of the knockout punch is to

a. drill holes in metal.
b. remove knockouts from boxes.
c. enlarge holes in sheet metal.
d. reduce the size of holes in boxes.

34. (220) What tool is used to remove insulation from small-size wires up to No. 12 AWG?

a. Reamer.
b. Wire stripper.
c. Lineman's pliers.
d. Needlenose pliers.

35. (221) Which of the following soldering devices are nonelectric?

a. Soldering gun and heat sinks.
b. Soldering torch and soldering gun.
c. Soldering gun and soldering copper.
d. Soldering copper and soldering torch.

36. (222) A soldered connection that is dull white is called a

a. hot solder joint.
b. cold solder joint.
c. bad solder joint.
d. good solder joint.

37. (223) What determines the size of the bit shank that can be used in a portable electric drill?

a. HP of drill.
b. Size of chuck.
c. RPM of drill.
d. Size of motor.

38. (223) The spade bit is sometimes referred to as a

a. metal bit.
b. speed bit.
c. wood auger.
d. quick auger.

39. (224) What is the largest AWG size electrical wire?

a. 4/0.
b. 6/0.
c. 12.
d. 40.

40. (224) Conductors made in MCM sizes range from

a. 100 MCM to 1000 MCM.
b. 200 MCM to 2000 MCM.
c. 250 MCM to 2000 MCM.
d. 350 MCM to 3500 MCM.

41. (224) What do the letters THW marked on an electrical conductor indicate?

a. Heat-resistant asbestos.
b. Heat- and weather-resistant rubber.
c. Temperature, heat, and weather resistant.
d. Heat- and moisture-resistant thermoplastic.

42. (225) Prepunched disks in a box that can be removed easily to permit conduit or cable connectors to be installed are called

a. connector disks.
b. knockouts.
c. priouts.
d. blanks.

43. (226) What is the purpose of a raised box cover?

a. Provides space for three additional devices.
b. Provides added interior space as well as a cover for the box.
c. To allow for installation of a thicker wall surface after the box is mounted.
d. To allow the box to be mounted 5/8 of an inch behind the wall surface.

44. (227) When lengths of rigid metal conduit are jointed together, the fittings normally used are

a. threaded couplings.
b. threaded connectors.
c. compression couplings.
d. compression connectors.

45. (227) Flexible metal tubing <u>cannot</u> be used in sections greater than

a. 3 feet in length.
b. 6 feet in length.
c. 9 feet in length.
d. 12 feet in length.

46. (228) Which conductor must a single-pole switch open when properly installed in a circuit?

a. Ungrounded conductor.
b. Grounding conductor.
c. Grounded conductor.
d. Neutral conductor.

47. (228) What is the highest position the handles of switches and circuit breakers can be installed from the floor or a working platform?

a. 48 inches.
b. 54 inches.
c. 60 inches.
d. 78 inches.

48. (229) Dryer outlets installed in homes are normally rated at

a. 20 amps.
b. 30 amps.
c. 40 amps.
d. 50 amps.

49. (229) The NEC allows a 30-ampere, crow's foot, three wire outlet to be used without an equipment ground if the neutral in the appliance cord is

a. No. 10 AWG and bonded to the frame of the appliance.
b. No. 12 AWG and bonded to the frame of the appliance.
c. No. 8 AWG and bonded to a cold water pipe.
d. No. 6 AWG and bonded to a driven earth ground.

50. (230) Which classification of light directs from 40 to 60 percent of its light upward above the area to be lighted?

a. Indirect.
b. Semidirect.
c. Semi-indirect.
d. General diffusing.

51. (231) Select an advantage of incandescent lighting over fluorescent lighting.

a. Produces less heat.
b. Ease of maintenance.
c. Gives off more light.
d. Greater efficiency per watt.

52. (231) The three basic types of fluorescent lights are rapid start, instant start, and

a. cold cathode.
b. auto start.
c. lag start.
d. preheat.

53. (232) Compared to incadescent bulbs of the same wattage, the new high-pressure sodium light bulbs

a. will use the same amount of power.
b. only requires three-quarters of the power.
c. will have a 50-percent increase in lamp life.
d. will have a 100-percent increase in lamp life.

54. (232) How can the stroboscopic effect of HID lights be reduced?

a. Adjacent lamps should be powered from different phases.
b. Each row of lamps should be powered from the same phase.
c. Reduce the ballast voltage 5 percent below the specified rating.
d. Alternate the HID lamps with incadesent lamps.

55. (232) What is another name for an HID lamp ballast?

a. A choke coil.
b. A phase splitter.
c. A capacitor filter.
d. A current-limiting transformer.

56. (233) An electrical system that uses two ungrounded conductors and a neutral conductor is a

a. two-wire, single-phase type.
b. two-wire, two-phase type.
c. three-wire, single-phase type.
d. three-wire, three-phase type.

57. (233) What type of conductors and how many conductors are required for a 3-phase wye service entrance used for power and lighting?

a. 3 ungrounded conductors.
b. 4 ungrounded conductors.
c. 2 ungrounded and 1 grounded neutral conductors.
d. 3 ungrounded and 1 grounded neutral conductors.

58. (233) What is the phase-to-phase voltage of a 3-phase, wye system when phase-to-neutral voltage is 120 volts?

a. 208.
b. 220.
c. 240.
d. 440.

59. (233) Which one of the following voltage systems has one phase to neutral voltage that is higher than other phases to neutral?

a. Two-wire, single-phase.
b. Three-wire, single-phase.
c. Four-wire, three-phase delta.
d. Four-wire, three-phase wye.

60. (234) The minimum clearance of service drop conductors above the ground or a sidewalk near residential buildings is

a. 14 feet.
b. 12 feet.
c. 10 feet.
d. 8 feet.

61. (234) What is the minimum clearance for a service drop over a public street?

a. 10 feet.
b. 12 feet.
c. 15 feet.
d. 18 feet.

62. (234) Power operated service disconnects are required to be designed so that they can be opened

a. externally.
b. manually.
c. quickly.
d. slowly.

63. (235) Why are service entrance conductors usually larger than the service drop conductors?

a. Free air permits greater ampacity on service drop conductors.
b. There is more amperage on the service drop conductors.
c. The voltage is higher on the service drop conductors.
d. There is less amperage on service drop conductors.

64. (235) When the service drop conductors are supported by being attached to the rigid metal conduit enclosing the service entrance conductors, the conduit is referred to as a service

a. mast.
b. head.
c. frame.
d. attachment.

65. (235) Two methods of preventing rain from entering service-entrance cable are to use a weatherhead or

a. a rain cap.
b. a gooseneck.
c. a junction box.
d. an entrance ell.

66. (236) Underground services installed with cable must be buried to a depth of at least

a. 18 inches.
b. 24 inches.
c. 30 inches.
d. 36 inches.

67. (237) In a panel with a neutral, what percent of the overcurrent devices must be rated at 30 amperes or less for it to be classified as a lighting and appliance panel?

a. 5 percent.
b. 10 percent.
c. 20 percent.
d. 25 percent.

68. (237) Other than clearly tagged, how is the high-voltage leg of a 4-wire grounded delta system identified?

a. Orange outer finish.
b. Black outer finish.
c. Brown outer finish.
d. Red outer finish.

69. (238) When installing a panelboard in a damp location, what is the minimum distance the cabinet must be placed from the wall?

a. 1/8 inch.
b. 1/4 inch.
c. 3/8 inch.
d. 1/2 inch.

70. (238) The equipment ground bar and neutral bar are bonded together in a panel <u>only</u> when the panelboard also serves as the

a. load center.
b. service lateral.
c. service equipment.
d. distribution feeder.

71. (238) The purpose of balancing the load on a panelboard is to

a. reduce voltage drop.
b. increase voltage drop.
c. reduce total current flow.
d. increase neutral current flow.

72. (239) A hexagon window on a plug fuse indicates that the amperage rating of the fuse is some value between

a. 0 and 15 amps.
b. 16 and 30 amps.
c. 31 and 45 amps.
d. 46 and 60 amps.

73. (239) What are the three classes of circuit breakers?

a. Thermal, magnetic, and time delay.
b. Thermal, magnetic, and combination thermal-magnetic.
c. Instantaneous, time delay, and intermediate.
d. Instantaneous, combination, and intermediate.

74. (239) Which one of the following circuits in a home requires the use of a GFCI type circuit breaker?

a. 120V/20 amp receptacles in bathrooms.
b. 120V/20 amp receptacles in bedrooms.
c. 240V/50 amp range circuit.
d. 240V/30 amp dryer circuit.

75. (240) Which type of electrical grounding consists of connecting all exposed noncurrent-carrying metal parts to the earth?

a. System.
b. Lighting.
c. Equipment.
d. Ground rod.

76. (241) Normally, a metal underground water pipe can be used as the primary grounding electrode when it is in direct contact with the earth for

a. 8 feet.
b. 10 feet or more.
c. 15 feet or more.
d. more than 20 feet.

77. (241) The maximum permissible resistance between the grounding electrode and earth is

a. 6 ohms or more.
b. 15 ohms or more.
c. 25 ohms or less.
d. 50 ohms or less.

78. (242) The conductors between the final overcurrent devices and the outlets for connecting electrical equipment are called

a. supply conductors.
b. feeder conductors.
c. distribution conductors.
d. branch circuit conductors.

79. (242) Which one of the following systems would not need a feeder circuit?

a. Distribution panel and service equipment are combined.
b. Service equipment and panelboard are separate.
c. Main panelboard serving panelboards in other parts of building.
d. Main panelboard delivering power to a panelboard with final overcurrent devices.

80. (243) If you wanted to find where to locate an outlet above a kitchen sink, what part of the blueprint would you check?

a. Plot plan.
b. Floor plan.
c. Sectional drawing.
d. Interior elevation.

81. (244) Which electrical diagram does not show the relative position of the parts of the system?

a. Block diagram.
b. Wiring diagram.
c. Schematic diagram.
d. Connection diagram.

82. (245) Blueprint circuit diagrams do not show

a. switch type.
b. switch location.
c. fixture location.
d. wiring connections.

83. (246) What is the general lighting load of a single dwelling with 1600 square feet of living area?

a. 480 watts.
b. 533 watts.
c. 4800 watts.
d. 5333 watts.

84. (246) How many 115 volt, 15 amp, lighting circuits are required to evenly distribute a 5,405 watt lighting load?

a. Two.
b. Three.
c. Four.
d. Five.

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85. (247) A branch circuit load, rated continuous, should be calculated with an increase of

a. 10 percent.
b. 15 percent.
c. 20 percent.
d. 25 percent.

86. (247) What is the total wattage of 9 ballasts rated at 1.5 amps each and fed by 277 volts?

a. 1,350 watts.
b. 3,739 watts.
c. 4,155 watts.
d. 42,930 watts.

87. (247) Heavy duty lamp-holder outlets are calculated at

a. 300 volt-ohms.
b. 300 volt-amperes.
c. 600 volt-ohms.
d. 600 volt-amperes.

88. (247) What is the required wattage, for lighting, of an industrial commercial (loft) building measuring 60 X 100 foot?

a. 6,000 watts.
b. 12,000 watts.
c. 18,000 watts.
d. 24,000 watts.

89. (248) Ampere capacity of branch-circuit conductors feeding a motor circuit will be <u>not less than</u>

a. 100 percent of the motors FLC.
b. 125 percent of the motors FLC.
c. 150 percent of the motors FLC.
d. 200 percent of the motors FLC.

90. (249) To prevent nuisance tripping on a welder circuit, we are allowed to install overcurrent protection at what percent of the calculated load?

a. 125 percent.
b. 150 percent.
c. 175 percent.
d. 200 percent.

91. (249) To determine the total calculated load of a sub-panel, you add all the amperages of the branch circuits plus what percent of the amperage of the largest motor?

a. 10 percent.
b. 15 percent.
c. 25 percent.
d. 30 percent.

92. (250) How many conductors can be installed in raceway before the current capacity of the conductors must be derated to 80% of their capacity?

a. 3.
b. 4.
c. 5.
d. 6.

93. (250) The main thing to remember in paralleling conductors in raceway is

a. all conductors must be the same color.
b. phases and neutrals must be separated.
c. all neutral conductors must be in the same raceway.
d. each neutral is run with its corresponding phases.

94. (251) The key to CE shops working together is

a. to coordinate.
b. to cooperate.
c. to communicate.
d. to capitulate.

95. (252) The cubic inch capacity of a box is determined by

a. outside dimensions.
b. depth and width.
c. depth and length.
d. depth, width, and length.

96. (253) A quick easy method of mounting boxes to metal studs is to use

a. metal studs.
b. twist anchors.
c. spring metal clips.
d. self tapping screws.

97. (254) NMC, but <u>not</u> NM cable, can be used in

a. corrosive locations.
b. two family dwelling.
c. dry locations.
d. air voids.

98. (254) Aluminum conductors used in nonmetallic cable range in size from

a. No. 14 to No. 6 AWG.
b. No. 14 to No. 2 AWG.
c. No. 12 to No. 4 AWG.
d. No. 12 to No. 2 AWG.

99. (255) NM cable, run at right angles across ceiling joists on 16-inch centers, should be stapled

a. on every joist.
b. on every second joist.
c. on every third joist.
d. only within 12 inches of a box or cabinet.

100. (255) NMC cable No. 8 AWG, or larger, may be held in place by EMT straps

a. in a concealed area only.
b. in a finished basement area.
c. on smooth walls and exposed cable.
d. only when the cable passes through one floor to another.

101. (255) Most NM cable ordered for branch circuits is

a. No. 10/3 with ground, in 200 ft coils.
b. No. 12/2 with ground, in 200 ft coils.
c. No. 10/2 with ground, in 250 ft coils.
d. No. 12/2 with ground, in 250 ft coils.

102. (256) A solderless pigtail splice is finished with

a. a wire nut.
b. epoxy resin.
c. plastic tape.
d. rubber and friction tape.

103. (257) If a circuit is to be wired with nonmetallic sheathed cable, the equipment grounding conductor will be

a. white.
b. white or neutral gray.
c. bare, green, or green with yellow stripes.
d. any color other than black, white, or green.

104. (258) The maximum weight of a fixture that can be supported by an outlet box is

a. 10 pounds.
b. 20 pounds.
c. 40 pounds.
d. 50 pounds.

105. (259) What is the taper per foot of a standard conduit-cutting die used on rigid metal conduit?

a. 1/4 inch.
b. 1/2 inch.
c. 3/4 inch.
d. 1 inch.

106. (259) What is considered a "full thread" when using a standard cutting die on rigid metal conduit?

a. One full turn of the cutting die.
b. Sixteen full turns of the cutting die.
c. Three-quarters of an inch of running thread.
d. Three threads extended beyond the cutting die.

107. (260) Two adjacent 90-degree bends in the same piece of conduit make up a

a. double offset.
b. double right angle.
c. back-to-back bend.
d. pair of offset 90s.

108. (260) Two equal conduit bends in opposite directions, used to avoid contacting a part of the structure, are called

a. a back-to-back.
b. an offset.
c. a saddle.
d. a strap.

109. (261) What is the distance between supports on direct vertical runs of rigid conduit form machine tools if threaded couplings are used and the riser is supported at each end?

a. 20 feet.
b. 10 feet.
c. 8 feet.
d. 5 feet.

110. (262) The number of conductors you can put in conduit is based on the

a. size of conduit, conductor insulation, and length of run.
b. size of conduit, conductor insulation, and conductor size.
c. insulation of conductor, length of run, and number of bends.
d. size of conductor, length of run, and number of bends.

111. (263) Which of the following materials should be used for a circuit extension when appearance is an important factor?

a. Rigid conduit.
b. Surface raceway.
c. Multioutlet assembly.
d. AC cable and MI cable.

112. (264) The purpose of any meter is to measure

a. line loss.
b. quantities.
c. power source.
d. operating principles.

113. (265) If you make a false meter reading due to reading the pointer position from an angle, it is called

a. parallax.
b. parallel.
c. deflection.
d. inflection.

114. (266) Most AC or DC voltmeters use a

a. galvanometer-type movement connected in series with a high resistance shunt.
b. galvanometer-type movement connected in parallel with a high resistance shunt.
c. dynamometer-type movement connected in parallel with a high resistance shunt.
d. dynamometer-type movement connected in series with a high resistance shunt.

115. (266) The fixed resistors in an ohmmeter are of such value that if the test probes are shorted together, the meter will

a. be damaged.
b. read infinity.
c. read full scale.
d. deflect past zero.

116. (267) When the PSM-6 is used as a DC voltmeter, the function switch should be placed in what position for the most accurate meter reading?

a. DC/1Ω/V.
b. DC/1KΩ/V.
c. DC/10KΩ/V.
d. DC/20KΩ/V.

117. (267) For a PSM-6, what increase of DC voltage meter-range is provided by using the accessory "PROD TEST"?

a. 1,000 volts.
b. 5,000 volts.
c. 10,000 volts.
d. 50,000 volts.

118. (268) No matter which voltage indicator is used, to read the circuit voltage, it must be connected in

a. parallel with the power source.
b. parallel with the load.
c. series with the power source.
d. series with the load.

119. (268) Never use an indicator test-lamp on a circuit where you suspect

a. the voltage is higher than the lamp rating.
b. the circuit is grounded out.
c. a shorted circuit.
d. an open circuit.

120. (269) Most serious difficulties within an electrical system can be detected by

a. a load check.
b. an overhaul of the system.
c. a personal observation.
d. a tear down and parts inspection.

121. (270) Grounds or short circuits can be

a. solid, partial, or floating.
b. solid, partial, or frequent.
c. solid, frequent, or floating.
d. partial, frequent, or floating.

122. (271) The basic factor to consider in choosing continuity testing equipment is to use

a. high-current instruments for accuracy.
b. low-power draw instruments to save energy.
c. low-resistance instruments to prevent arcing.
d. low-voltage instruments to reduce the danger of sparking.

123. (272) When troubleshooting for a blown fuse with a voltmeter, the easiest method is to read between the

a. two fuses.
b. top of adjacent fuses.
c. bottom of adjacent fuses.
d. top and bottom of the suspected fuse.

124. (273) A short circuit exists when there is a direct connection between two wires or conductors

a. to ground.
b. of the same potential.
c. of different potentials.
d. with excessive resistance.

END OF EXERCISE

## STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 44 USC 3101. PRINCIPAL PURPOSE(S): To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with every ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI. DISCLOSUR oluntary. The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information would result in slower action or inability to provide assistance.

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# ELECTRICIAN

**(AFSC 54250)**

**Volume 3**

***Installation and Maintenance of Motors,***

***Controls, and Special Equipment***

## Extension Course Institute
## Air University

448

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# Preface

THIS VOLUME OF CDC 54250, *Electrician,*, is primarily concerned with the installation and maintenance of motors, motor controls, and special purpose equipment. It also contains information on the installation and maintenance of transformers, voltage regulators, battery banks and charges, emergency lighting, appliances and equipment installed in hazardous locations, alarm systems, cathodic protection, and the general contingency responsibilities of an electrician.

Code numbers appearing on figures are for preparing agency identification only and should be of no concern to the student.

Direct your questions or comments relating to the accuracy or currency of this volume to the course contact: 3700 TCHTW/ TTGXF, ATTN: MSgt Jerome E. Pollock, Sheppard AFB 76311. If you need an immediate response, call the author, AUTOVON 736–2087 or 4340, between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

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This volume is valued at 48 hours (16 points).

Material in this volume is technically accurate, adequate, and current as of July 1982.

# Contents

**NOTE: In this volume, the subject matter is developed by a series of student-centered objectives. Each of these carries a three-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see whether your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.**

# Motors and Motor Control Circuits

IN ADDITION TO the responsibilities covered in the previous volumes of this CDC, an electrician is also responsible for the installation and maintenance of motors, motor controls, and special purpose equipment. This volume deals with these areas.

In this chapter, we will cover the theories of operation for motors and motor controls. You will also find information on how to install, maintain, inspect, and troubleshoot motors and motor controls.

## 1-1. Motors

In our world of automation, we take for granted one of the most efficient devices ever invented—the electric motor. It is estimated that 90 percent of industry uses motors. The average home application has increased over the past few years, ranging from small clock motors to the larger heating and air-conditioner motors. You, as an electrician, must understand the principle of operation and construction of electric motors and their control to perform troubleshooting, maintenance, and replacement.

The rotating machine used to convert electrical energy into mechanical energy is the electric motor. Practically all motors are designed to meet the requirements of a specific function. All electric motors fall into three basic types; direct current (DC), alternating current (AC), and universal. Let's look at the DC motor first.

**400. Name the major assemblies of a DC motor and explain the function of each component.**

**Direct-Current Motors.** The major parts of a DC motor include the armature, field assembly, frame, brush assembly, and endbells. See figure 1-1.

*Armature.* The armature is the rotating part of a DC motor. It consists of a laminated iron core, windings, and commutator, all mounted on a steel shaft. The core is laminated to reduce eddy currents. The windings are placed in slots of the laminated iron core and held in place by wooden or fiber wedges. The windings' ends are brought out and connected to the correct commutator segments. The commutator is made of segments of hard-drawn c  er, insulated from each other by sheets of mica. Th  ised portion of each commutator segment is called a r  . The coil ends from the armature windings are solde  d to the riser. The commutator segments connect the stationary terminals (or brush circuit) to the rotating armature windings.

*Field assembly.* The field assembly consists of the pole pieces and field coils. The poles are usually laminated and are bolted to the inside of the frame. The windings are placed around the pole pieces. The field windings are connected so that they produce alternate north and south poles. The number of pole pieces in DC motors is always an even number.

*Frame.* The frame, sometimes referred to as the housing, is made of cast or fabricated steel. The frame has many functions. It serves as a means of support for the motor and completes the magnetic circuit. The housing has high permeability and, with the field poles forms the major part of the magnetic circuit.

*Brush assembly.* The brush assembly consists of the brushes, brush holders, and springs. The brushes ride on the surface of the commutator and form the electrical contact between the armature windings and the external circuit. Brushes are usually made of high-grade carbon and are held in place by brush holders, which are insulated from the frame.

The brushes must be free to slide up and down in their holders so that they can follow irregularities on the surface of the commutator. A flexible braided copper conductor (pigtail) connects each brush to the external circuit. Pressure is exerted on the brush by a spring.

*Endbells.* The endbells are fastened to the housing by means of bolts and serve to keep the armature in position. The endbells house the bearing and center the armature so that it can rotate without rubbing against the field poles.

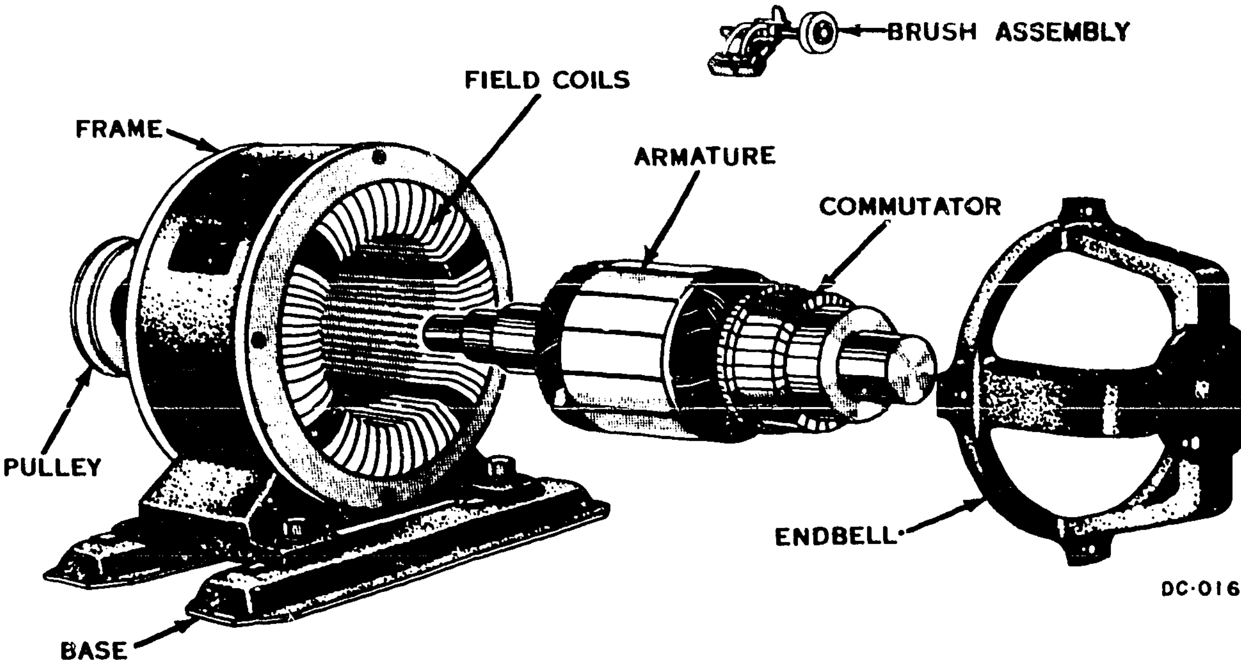


Figure 1–1. Parts of a DC motor.

**Exercises (400):**

1. Name the five major parts of any DC motor.

2. What is the relationship of the commutator to the armature?

3. How are the pole pieces attached to the frame?

4. Where are the field coils placed?

5. How is a circuit completed from the commutator to the external power?

6. What is the primary functions of tne endbells?

**401. Explain the principles of operation of a DC motor and distinguish among the three basic types.**

**Operating Principles of DC Motors.** To understand the principles on which electric motors operate, it is necessary to review magnetism and magnetic induction. The basic law is that "unlike poles of a magnet attract and like poles repel each other."

If we take a soft-iron core (pole piece) and place a coil of wire (field coil) around it, we have an electromagnet. When current passes through the winding, it will produce a definite polarity in the pole piece. The direction of current flow through the winding determines the polarity. You may want to review Volume 2 of this CDC on magnetism and the left-hand rule in determining the polarity of an electromagnet.

In operation, a magnetic field of permanent polarity is set up in the field poles when DC current flows through the field windings. The current that is applied through the brushes and commutator segments into the armature coil also produces a magnetic field. See figure 1-2. The armature's magnetic field is attracted by the magnetic field around the pole pieces. This attraction causes the armature to turn. Before the magnetic fields can line up with each other, the energized commutator segments have rotated past the br ɔn contact point.

Now concentrate on figure 1-2. What will happen to the position of our brushes and the commutator segments as the armature is turning? The left-hand brush will now come into contact with the right half of the commutator segment. The brush on the right half of the figure will now contact the commutator segment that was on the left. Now stay with

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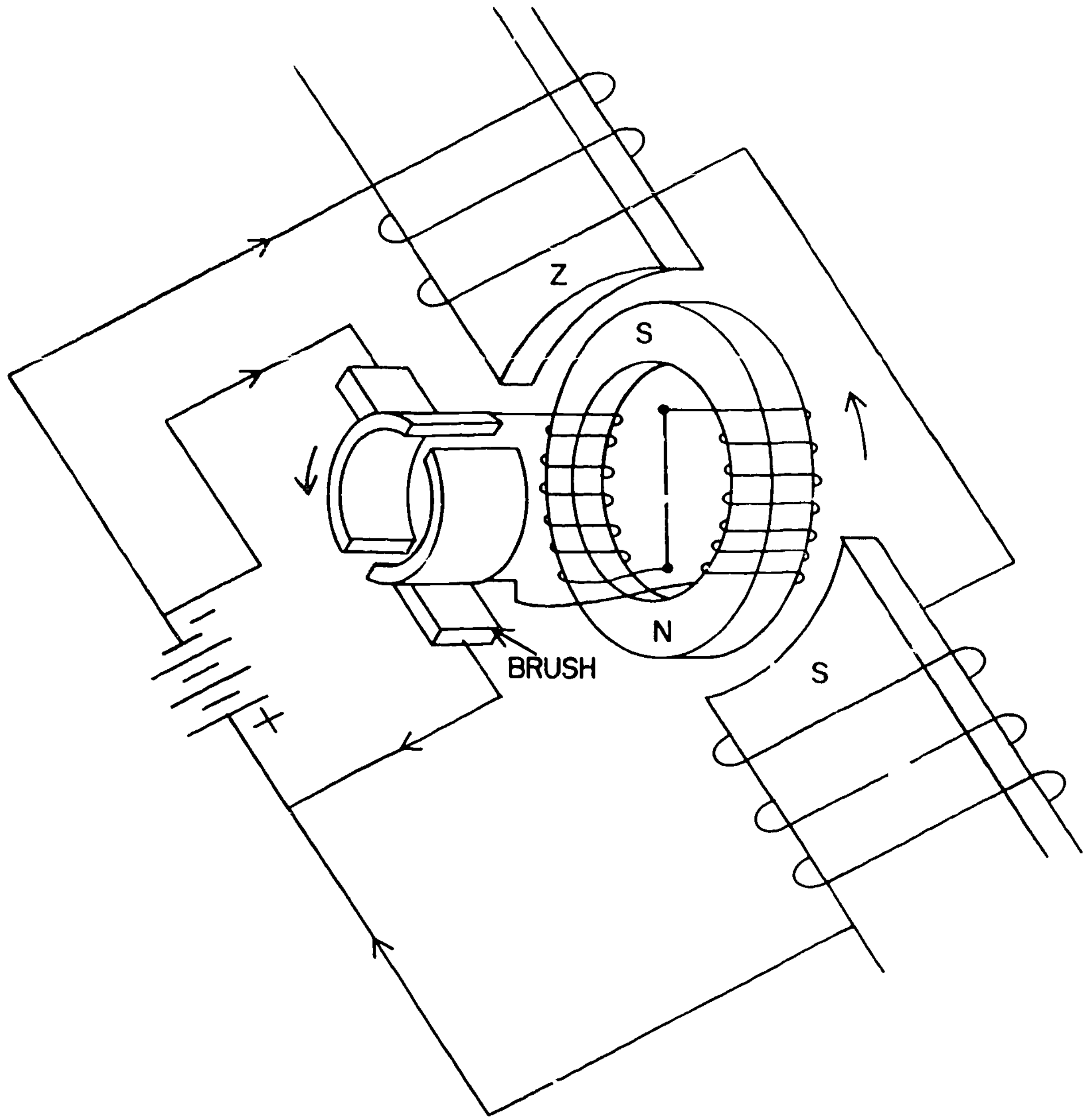


Figure 1–2. DC motor.

me. What has happened is the direction of DC current has been reversed through the armature coil. The positive DC brush on the right of figure 1-2 will energize the opposite end of the armature coil than it did before. If we have reversed the DC current through the armature coil, we have also reversed the north and south magnetic poles in the armature. All through the reversal action of the armature field, the armature has continued to turn so that the armature field and the permanent field have just passed through center. In other words, both magnetic fields are just past a point where they would line up with each other. But now we have like poles (north facing north and south facing south) opposite each other. The law of magnetism tells us these like poles will repel, so the stationary field poles repel or push the armature further past the center point. The armature continues to turn and the opposite, or unlike, field pole begins to attract the armature field as it continues to revolve. At this point, we are back to where we started. An actual motor would have many coils on the armature and an equal number of commutator segments. This would allow a stronger attracting and repelling action and thereby a more uniform and smoother turning force. All motors operate on this basic principle of attracting or repelling magnetic fields.

The three basic DC motors are the series, shunt, and compound. DC motors are classified by the way in which the armature and field windings are connected to power.

*Series motor.* A series DC motor is connected so that the armature and field windings are in series, as shown in figure 1-3,A. The entire current flows through both the field and armature windings which produces a high starting torque. The distinguishing characteristic of a series motor is that speed changes rapidly with load. When load is high, speed is low and when load is low, speed is high. Therefore, a series motor should never be operated without a load. It has no speed control except its load and may disintegrate due to excessive speed if operated unloaded. The series motor is used when high starting torque is required and rapid fluctuations of torque occur.

*Shunt motor.* A DC shunt motor has the field coils and armature connected in parallel, as you can see in figure 1-3,B. The resistance in the field windings is high; therefore, the current flow through the field is low. Since the field windings are connected directly across the power supply, the current will remain constant. The field current does not vary with motor speed, as in the series motor, so torque of the shunt motor will vary only with the current through the armature. The speed of a shunt motor varies very little when load changes. Shunt motors are used when constant speed is desired and when high starting torque is not required.

*Compound motor.* A compound motor is connected so that part of the field windings is connected across the power supply, and the other part is connected in series with the armature (see fig. 1-3,C). By this method, the characteristics of the series motor and shunt motor are combined. A series field connection and an armature connection provide high starting torque, while the shunt field windings provide for speed control. A compound motor has the advantages of high starting torque and good speed regulation under load.

**Exercises (401):**

1. The magnetic law that applies to the operation of DC motors states that unlike magnetic poles __________.

2. What determines the polarity of an electromagnet?

3. What rule could you use to determine the polarity of an electromagnet?

4. What causes the current flow to reverse in the armature winding of a DC motor?

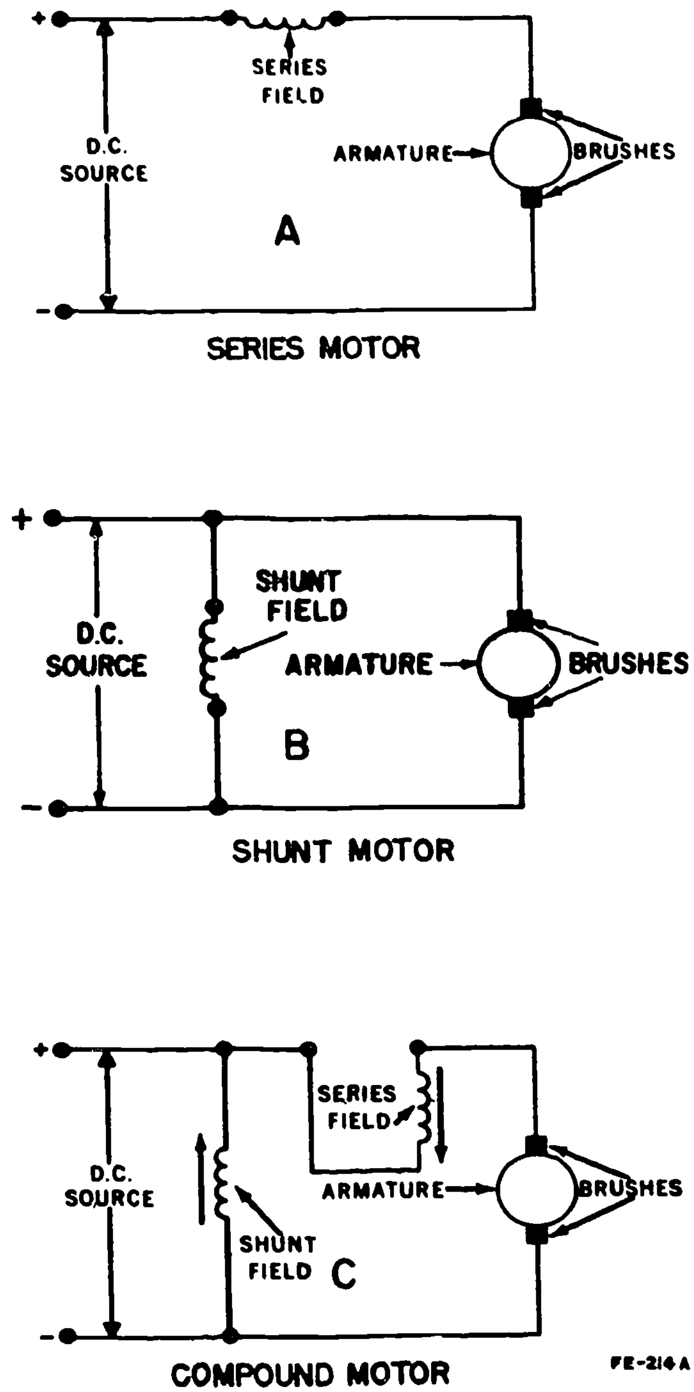


Figure 1–3. General types of DC motors.

5. What force(s) causes the armature of a DC motor to rotate?

6. Name the three types of DC motors.

7. State the type of DC mo' at you should use in each case below:

   ——— a. When high starting torque is required and rapid fluctuations of torque occur.

   ——— b. When constant speed is required and high starting torque is not required.

   ——— c. When high starting torque is required with good speed control.

8. Which DC motor should not be operated without a load?

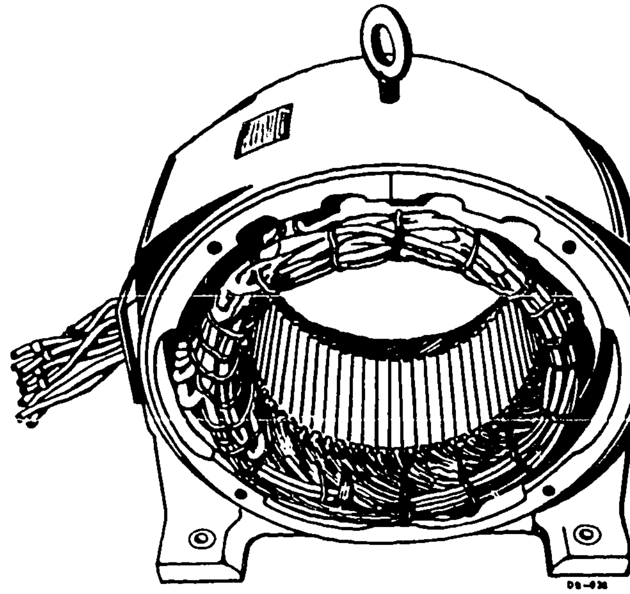

Figure 1-4. Three-phase stator.

**402. Name specified parts of a three-part (3ϕ) induction motor and identify the functions of selected parts.**

The two general types of 3ϕ motors are induction and synchronous. Both motors depend on the existence of a rotating magnetic field for their operation. The construction of the rotors is the basic difference of these AC motors. We will only cover the induction type.

**Types of 3ϕ Induction Motors.** The most common types of 3ϕ induction motors are the squirrel-cage rotor and the-wire wound rotor, also called an armature. 3ϕ motors, sometimes referred to as polyphase motors, all have three basic parts: stator, rotor, and endbells.

*Stator.* The stator, or frame, serves to house the stationary windings and provide an attachment point for the supply voltage. The stator is illustrated in figure 1-4. It is made of cast iron or steel and has a silicon steel core pressed inside. The steel core is constructed with semiclosed slots which hold the field windings. The field windings are made up of a number of varnish-insulated coils, which are separated by 120 electrical degrees, or 1/3 cycle of AC power. The coils are insulated from the core with treated paper called fish paper. The coils are connected to form three separate windings. The field windings and the steel core together make up the stator part of the motor.

*Rotor.* The rotor is the rotating part of the motor. The rotor provides a point to convert electrical energy to mechanical energy and to attach the motor to the load. Rotors may be either the wire-wound or squirrel-cage type, depending on the manufacturing and motor requirements. Squirrel-cage rotors are cheaper to build and require less maintenance than the wound rotor.

*a.* Squirrel-cage rotor. The squirrel-cage rotor is made up of a laminated iron core mounted on a spider or framework secured to the shaft. See figure 1-5. Bars of copper, aluminum, or any alloy which is a good conductor, are laid in slots in the core. All the bars are connected to end rings forming a complete current path. Smaller motors, less than one horsepower, may have the rotor cast in one piece and the rotor bars will be on an angle to the shaft. This is called SKEW, and the effect increases the torque of the motor. Squirrel-cage rotors do not contain any electrical connections to the power source, no insulation and no commutator or sliprings. The rotor bars and end rings together make up a squirrel-cage winding. Fan blades are added on the end of the rotor to provide ventilation.

*b.* Wound Rotor. The wound rotor in figure 1-6 has a laminated silicon steel core mounted on a shaft. The rotor windings are made of coils of copper wire similar to those used in the stator. The windings are connected, wye or delta, and the other ends of the windings are connected to sliprings and are connected externally to resistors for variable speed control and low starting current.

*Endbells.* The endbells serve three functions. They house the bearings, support and align the rotor and shaft, and complete the frame of the motor.

**Exercises (402):**

1. What are the basic parts of a 3ϕ induction motor?

2. Name the parts of a squirrel-cage rotor.

3. What functions do the endbells perform on a motor?

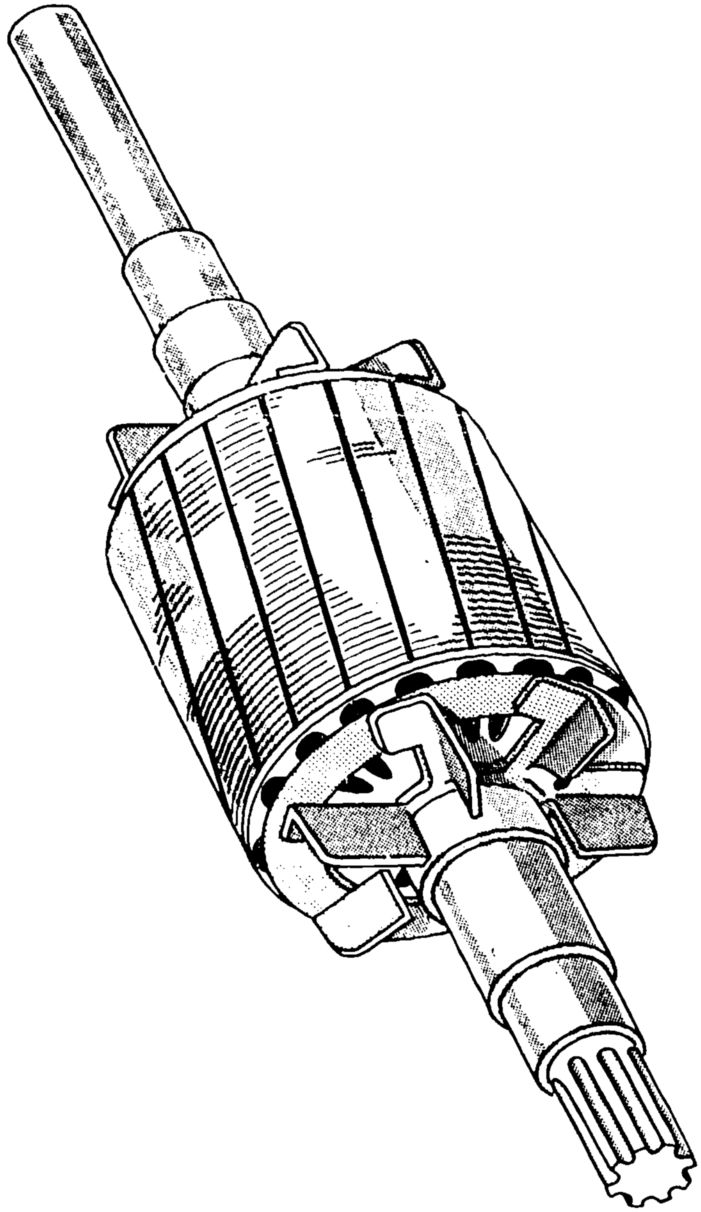

Figure 1-5. Squirrel-cage rotor.

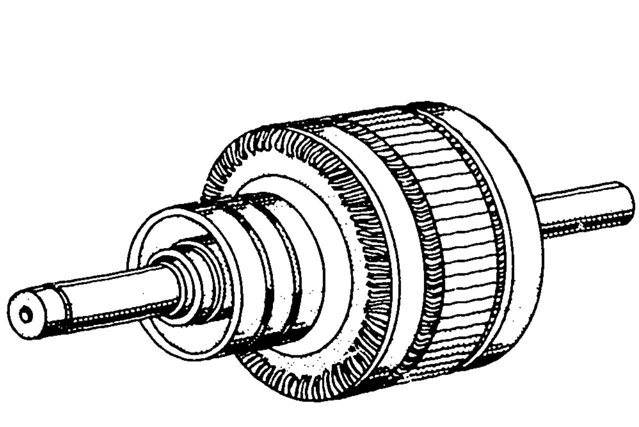

Figure 1-6. Three-phase wound rotor.

4. Which type of rotor has sliprings for variable speed control?

5. What is the purpose of the rotor in an AC motor?

6. Other than housing the stator windings, what function does a stator serve?

7. Why are laminated cores used in motors?

8. When is the use of a wound rotor desirable?

**403. Explain the principle of operation of a 3ϕ induction motor.**

**Operating Principles of 3ϕ Induction Motors.** A 3ϕ induction motor depends on a rotating magnetic field for operation. When current flows through the stator windings, a rotating magnetic field is produced that induces a voltage in the rotor. The current flow in the rotor sets up a magnetic field that is attracted to the rotating field in the stator. This rotating magnetic field is produced by several factors:

*a*. The difference in amount of current flow in the 3ϕ power caused by the characteristics of generating 3ϕ voltage.

*b*. The reversal in direction of current flow caused by the characteristics of voltage.

*c*. The arrangement of field windings in the stator core which establishes an even spread of the magnetic field around the stator.

The rotating magnetic field is set up by the rising and falling current in the stator windings as shown in the upper part of figure 1-7. When the current reaches its maximum value in one winding, this winding produces a strong magnetic field. As the current in the first winding decreases, the current in the next winding increases, causing the magnetic field to move to that winding. As the current decreases in the second winding, it increases in the third winding, causing the magnetic field to move again. The windings are distributed so that this rotation of the magnetic field is uniform and continuous.

Notice how the magnetic field rotates around the stator in the lower part of figure 1-7. These magnetic fields cut across the rotor, inducing voltage in the rotor. This voltage causes a current to flow in the rotor that produces a magnetic field. Since the voltage is induced, the magnetic field in the rotor will be opposite to the magnetic field that produced it. Proving the principle that unlike poles attract each other, the rotor follows the rotating magnetic field.

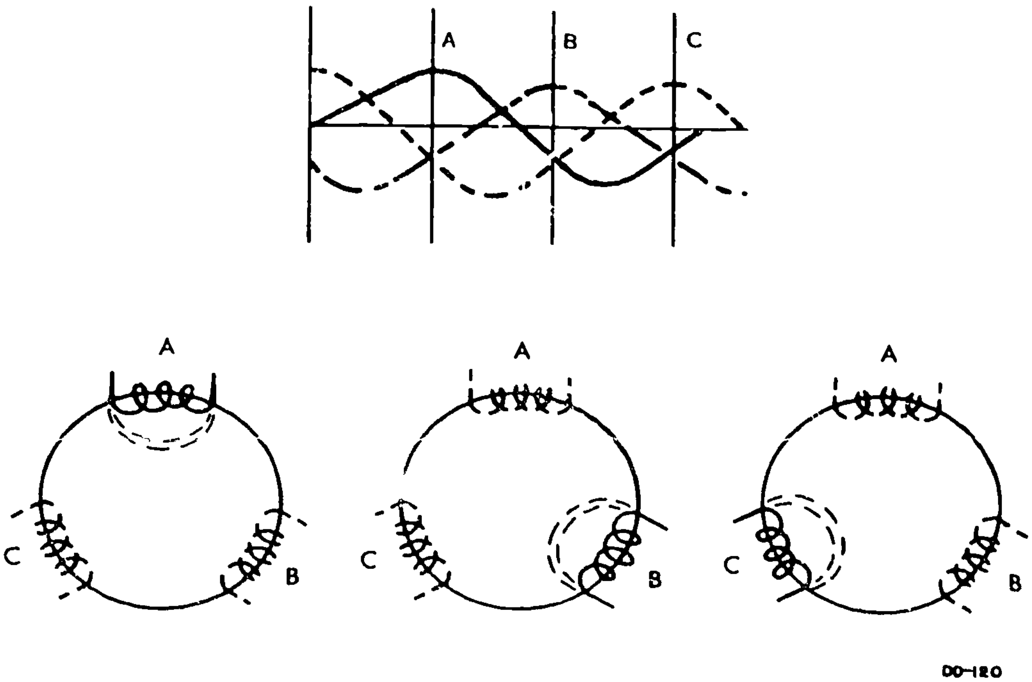


Figure 1–7. Rotating magnetic field schematic.

**Motor Speed.** The speed of the rotating field in the stator of an induction motor is called synchronous speed. Synchronous speed is determined by the number of poles in the motor and the frequency, which means that if frequency increases, motor speed increases. Speed is inversely proportional to the number of poles, which means the more poles a motor has, the slower it will turn. The equation for synchronous speed is:

$$\text{Revolutions per minute (rpm)} = \frac{\text{frequency} \times 120}{\text{no. of poles}}$$

Assume that we have an induction motor operating on 60 cycles, and the motor has 4 poles in the stator. Substitute these values for those in the formula.

$$\text{RPM} = \frac{60 \times 120}{4} = 1800$$

We find that the motor rotates at 1800 rpm minus the slip.

The speed of an induction motor is always less than that of the rotating magnetic field. This difference in speed is called slip. Normal slip for induction motors is from 2 to 5 percent of synchronous speed. If slip increases, torque increases. However, a slip of 25 percent is called stall point—a point at which the rotor stalls or locks. This is normally caused if the motor is overloaded.

For example, synchronous speed for a 4-pole motor is 1800 rpm. A data plate located on the stator will give the motor (shaft speed) as 1725 rpm. With these two figures slip can be determined as follows:

$$\text{Percent of slip} = \frac{\text{synchronous speed} - \text{rotor speed}}{\text{synchronous speed}} \times 100$$

$$\text{Percent of slip} = \frac{SS - rs}{SS} \times 100$$

$$\text{Percent of slip} = \frac{75}{1800} \times 100$$

$$\text{Slip} = 4.1 \text{ percent}$$

Normally you can obtain the rpm of a motor from the data plate. However, in some cases, the data plate will be missing from the motor. If the motor is operational, a tachometer can be used to determine speed of the shaft. A synchronous motor is one which operates at synchronous speed and, therefore, has no slip.

**Exercises (403):**

1. On what does the operation of a 3$\phi$ motor depend?

2. What is the difference in speed between the rotor and rotating magnetic field called?

3. What factors are necessary for producing a rotating magnetic field in a 3ϕ motor?

4. What is the synchronous speed of a 4-pole motor operating on 50-cycle power?

5. What is the normal slip for an induction motor?

6. What factors determine motor speed?

7. If frequency increases, what happens to motor speed?

8. What percentage of slip will cause the rotor to stall or lock?

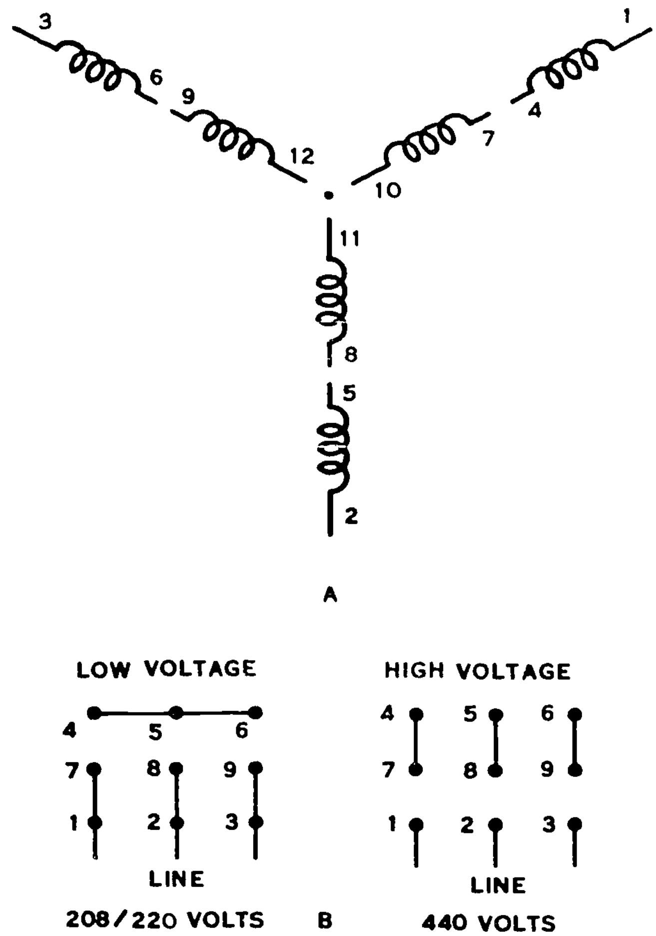


Figure 1–8. Three-phase wye connections.

**404. Describe the connections used for high and low voltage of a 3ϕ dual-voltage motor.**

**Three-Phase Motor Connections.** Three-phase motors have both internal and external connections to the stator coils. These coils are connected to each other internally to produce three separate windings or phases in the stator. The windings of all 3ϕ motors have either a wye or delta connection.

The internal connections determine if the windings require a delta or wye connection. The external connections are made with the leads that are brought out of the motor and connected to power.

Some 3ϕ motors are single voltage and others are dual voltage. This tells us that the single-voltage motor will operate at one particular voltage (for example, 220 volts). The dual-voltage motor will operate at two different voltages (for example, 220 or 440 volts), depending on how we make our external connections. A single-voltage 3ϕ motor will require only three leads to be brought out. A dual-voltage 3ϕ motor will normally have nine leads coming out of the motor. Each lead is one end of a stator coil, universally numbered for identification. An example is shown in figure 1-8. In the top right corner we see a schematic of one coil numbered 1 and 4. We will call this leads 1–4 as we continue our explanation. The coil just below 1–4 would be 7–10, which is our second half of one phase winding. We will series these coils for high voltage or parallel them for low voltage.

*Wye-connected motors*. The symbol for a wye-connected motor is Y, sometimes referred to as a star. Figure 1-8 shows a schematic diagram of a wye-connected dual-voltage motor. Leads 10, 11, and 12 are the ends of three separate coils and are connected together (normally this is completed inside the motor by the manufacturer). These leads are the internal connections that form the Y. The remaining nine leads are brought out of the motor for the external connections.

Notice in the figure that 208/220 volts is low voltage, and 440 volts is the high voltage. This information will be given on the motor data plate, which we will discuss later in this chapter. Let's look at the connections for both high and low voltage of a dual-voltage three-phase motor.

Figure 1-9 shows a 3ϕ wye-connected motor for low voltage (208/220 volts). The low-voltage connections are made by splicing leads 4, 5, and 6 together and taping the connection. Leads 1 and 7 are spliced together and connected to one of the leads of the 3ϕ power source.

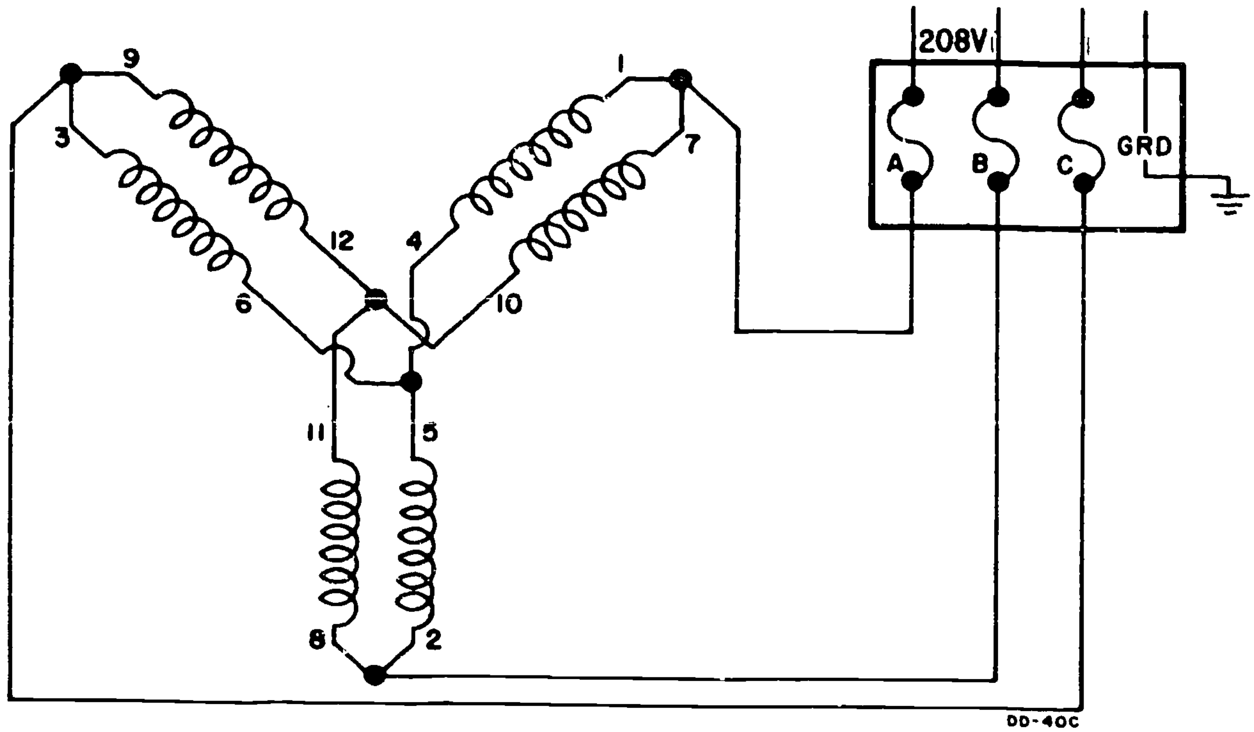


Figure 1–9. Wye-connected motor for low voltage.

Respectively, leads 2 and 8 and 3 and 9 are spliced and connected to the other two power source leads. Windings 1–4 and 7–10 are in parallel as well as 2–5 and 8–11, and 3–6 and 9–12. Placing these windings in parallel causes the impedance of the windings to decrease. If you recall your study of Ohm's law, when resistance decreases, current increases; therefore, when a motor is connected for low voltage, it will draw more current than if connected for high voltage.

Figure 1-10 shows a schematic diagram of a wye-connected motor for high voltage. Leads 1 through 9 are brought out of the motor in the terminal box. For high voltage, leads 4 and 7 are spliced together and taped, the same as 5 and 8 and 6 and 9. The 440-volt 3ϕ power source is connected to leads 1, 2, and 3. Each phase is connected separately and taped. For example, the A phase of power is connected to lead 1 of the motor. Thus, we have electrically connected the windings in series for high voltage.

*Delta-connected motors*. The symbol for a delta-connected motor is the Greek letter delta Δ. Figure 1-11 shows a dual-voltage delta-connected motor. Leads 10, 11, and 12 are connected inside the motor to leads 1, 2, and 3 respectively. Leads 1 through 9 are brought out in the terminal box of the motor.

Figure 1-12 shows a schematic diagram of a delta-connected motor for high voltage (440 volts). This is accomplished by connecting leads 4–7 together and taping the connection. Leads 5–8 and 6–9 are also spliced and taped. Leads 1, 2, and 3 are connected to the power source. This configuration has the windings placed in series for high voltage.

Figure 1-13 shows a schematic diagram of a delta-connected motor for low voltage. Connecting leads 1–6–7, 2–4–8, and 3–5–9, in this manner, places the windings in parallel. Therefore, we will have a higher current draw when connected for low voltage. Remember, leads 10, 11, and 12 are connected inside the motor to leads 1, 2, and 3.

As you can see by the schematic diagrams, placing the windings in series offers more impedance than the parallel connection. Therefore a motor connected for low voltage (connected in parallel) will draw more current than if connected for high voltage. You should understand that the current flow through each coil will be the same for high- or low-voltage connections. Figure 1-14 shows voltage drop across each coil for high- and low-voltage connections.

Remember, you must have 3ϕ power in order to operate a 3ϕ motor. Most 3ϕ motors are dual voltage, which enables them to operate on most 3ϕ systems; for example 3ϕ–220, 440, and 277/480 voltage systems.

To determine the direction of rotation of a 3ϕ motor, you should start it before the load is connected. If the rotation is incorrect, you can change any two power leads to reverse the rotation of the motor.

**Exercises (404):**

1. What are the two types of internal connections for a 3ϕ motor?

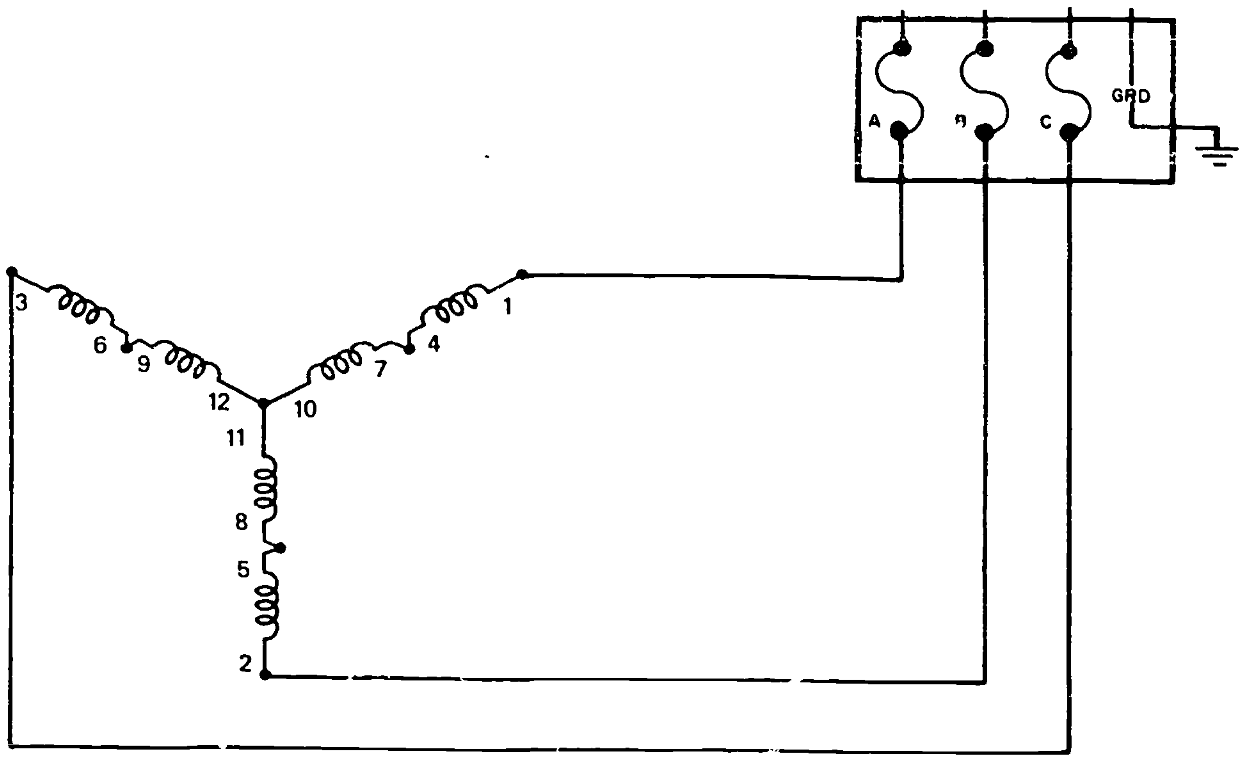


Figure 1–10. Wye-connected motor for high voltage.

2. What is the symbol for a wye-connected motor? A delta-connected motor?

3. How are the windings of a 3ϕ dual-voltage motor, whether wye or delta, connected for high voltage?

4. Which type of winding connection will cause a motor to draw more current, series or parallel?

5. What leads of a 3ϕ wye motor will connect to the power source leads when connected for high voltage?

6. What lead are the 440-volt 3ϕ power source connected to?

7. How many leads does a single-voltage 3ϕ motor require? A dual-voltage motor?

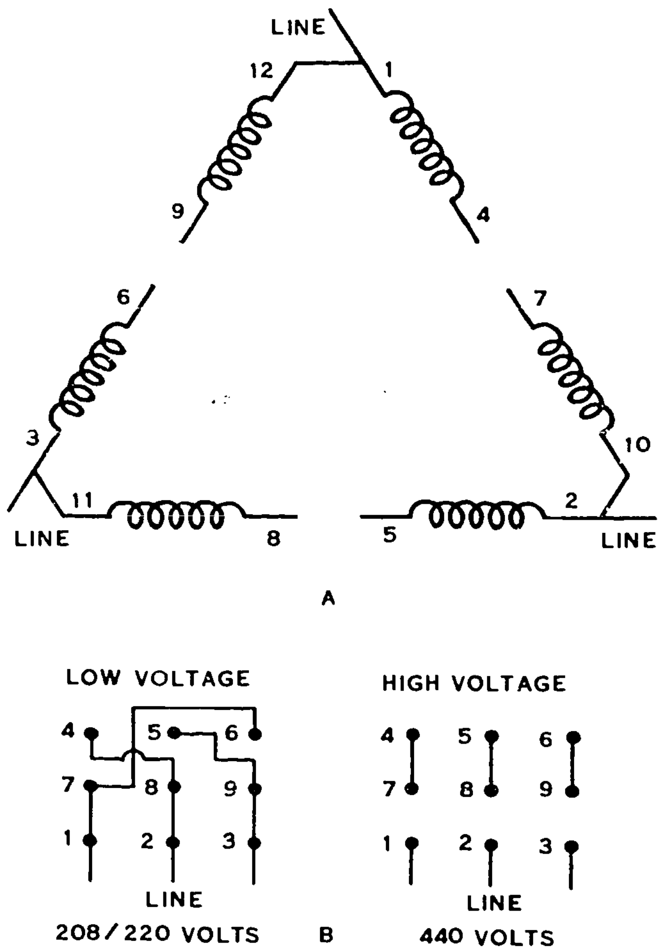


Figure 1-11. Three-phase delta connection.

**405. State the types and give operation details of 1$\phi$ AC induction motors.**

Most of the motorized appliances and machines found in the home are equipped with 1$\phi$ AC motors. Single-phase motors range from a fraction of a horsepower (hp) up to 10 hp. However, you will rarely find one over 2 hp. Single-phase motors are generally divided into two classes commutator and induction. Let's begin with the induction type. Of all AC motors, the induction motor is the most widely used. Its design is simple and sturdy. One of the major differences between a 1$\phi$ and a 3$\phi$ motor is that the 1$\phi$ motor requires some starting means, whereas the 3$\phi$ motor does not.

*Split-phase motors.* Split-phase motors are usually just fractional hp and are used to operate such devices as washing machines, small pumps, dryers, and blowers.

Basically, a split-phase motor is constructed the same as a 3$\phi$ motor. It has a stator, squirrel-cage rotor, and two endbells. The windings, however, are located and connected differently than they are in a 3$\phi$ motor. A centrifugal switch is also used during starting (fig. 1-15). A rotating part of the centrifugal switch is located on the rotor, and a stationary part (containing a set of contacts) is located in the endbell.

The rotating part of a centrifugal switch is a mechanism that relies on motion and flyweights to operate. As the rotor turns, the flyweights are pulled out by centrifugal force. This applies pressure to the closed contacts of the switch, causing them to open. These contacts are in series with the start winding. The opening of the contacts will deenergize the start winding.

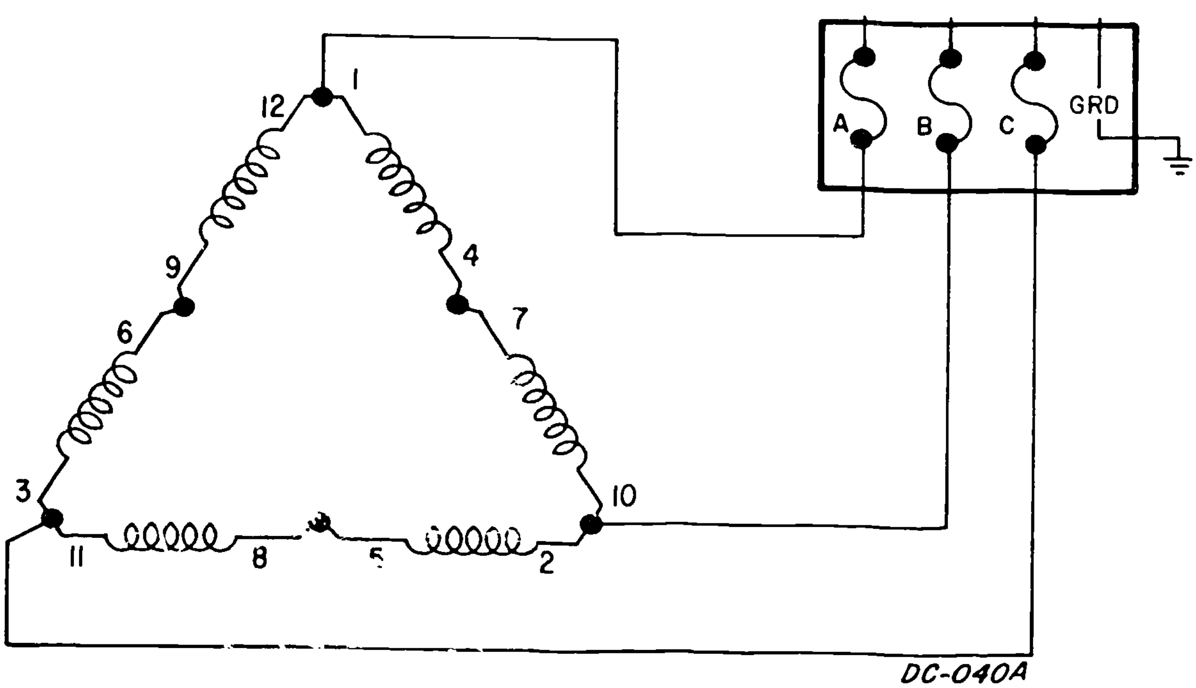


Figure 1-12. Delta-connected motor for high voltage.

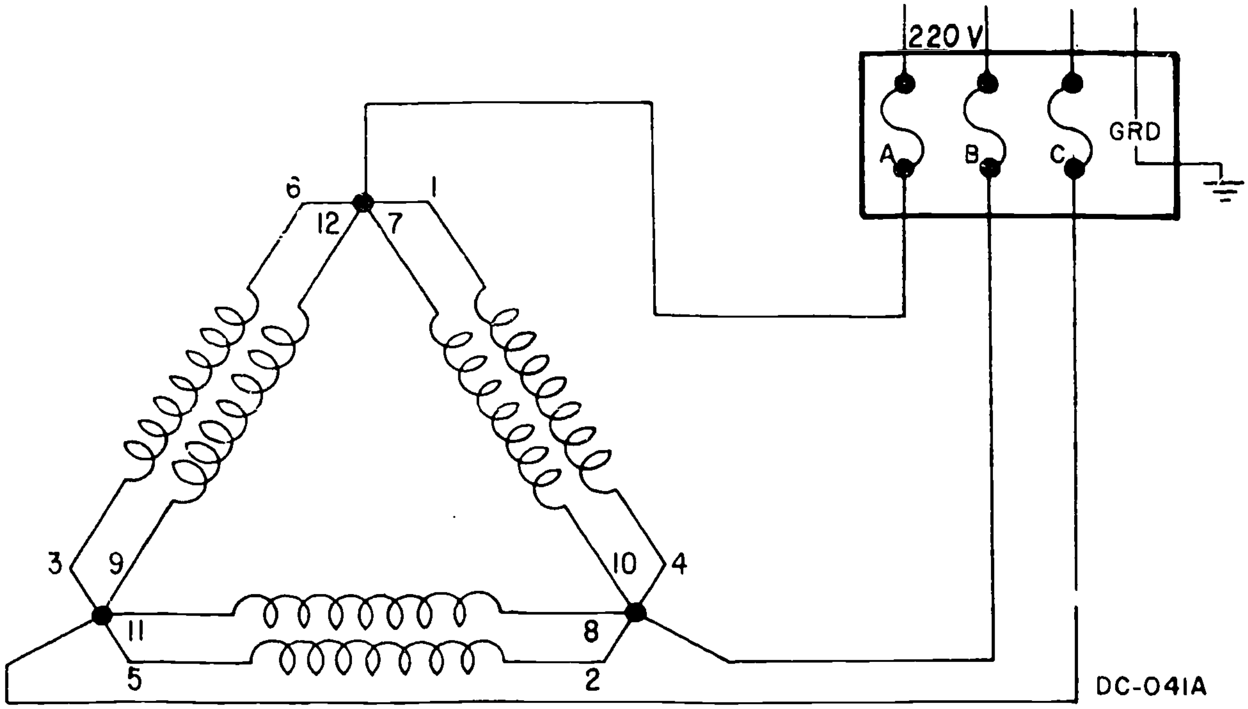


Figure 1–13. Delta-connected motor for low voltage.

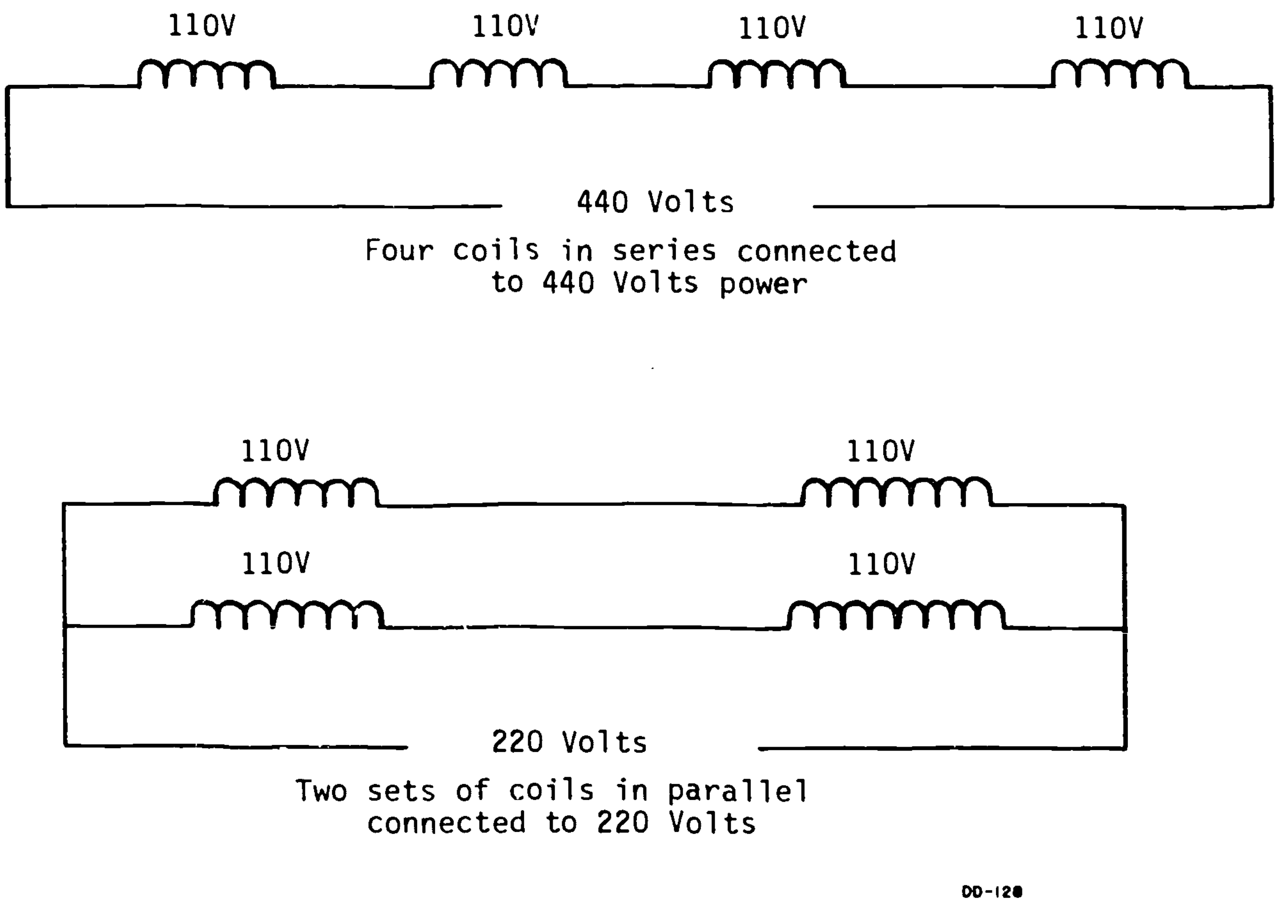


Figure 1–14. High- and low-voltage motor connections.

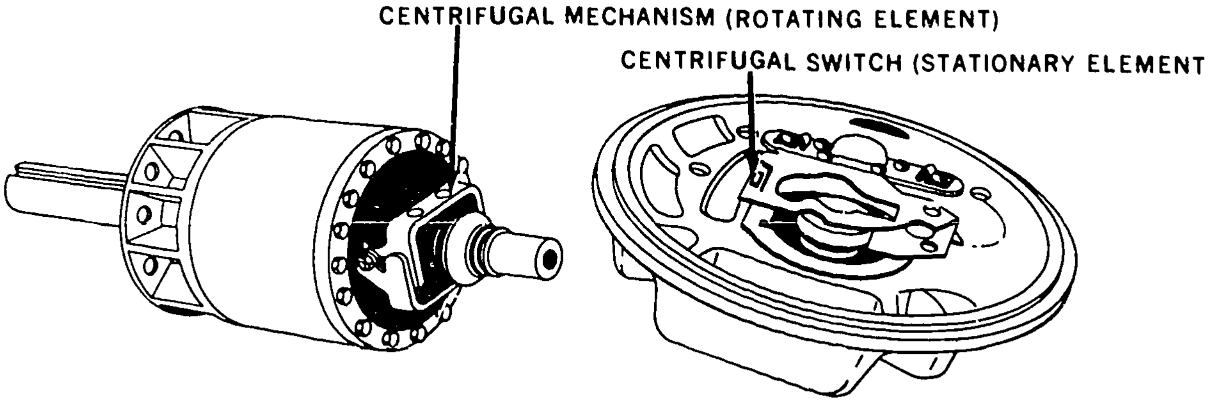


Figure 1–15. Components of a centrifugal switch.

Figure 1-16 is a schematic diagram of a split-phase motor. The split-phase motor has two windings. One winding is located at the bottom of slots in the stator, and is called the run winding or the main winding. The other winding is called the start winding and is located in the stator centered between and laid on top of the run winding. The start winding and the run winding are connected to power until the motor reaches 75 percent of its maximum rpm. The centrifugal switch then disconnects the start winding from the power. The run winding is made up of many turns of heavy copper wire; the start winding is made up of fewer turns of smaller wire. If the start winding is not disconnected after a short period of time, it will burn up.

When voltage is applied to both the start winding and run winding, the current in the run winding lags the voltage more than the current in the start winding. This creates a rotating magnetic field inside the stator. The rotating magnetic field induces a current in the rotor which sets up an opposing magnetic field. The magnetic fields combine in such a manner as to cause rotation of the rotor. The start winding is used only for starting the motor. After the rotor reaches a certain rpm, the start winding is disconnected by the centrifugal switch. After the start winding is cut out, the motor operates on a shifting magnetic field. The run current is shifting from positive to negative and back to positive.

*Capacitor-start motors*. A capacitor-start motor (see schematic diagram in fig. 1-17) is an improved version of the basic split-phase type of motor. The only difference is that an intermittent type of capacitor is connected in series with the start winding. When the motor reaches 75 percent of full speed, the centrifugal switch cuts out the start windings and the capacitor. The capacitor, along with the start windings, gives the motor a greater starting torque than a basic split-phase motor.

To create a starting torque in a capacitor motor, a stronger rotating magnetic field is established inside the motor. This is done by placing the start winding out of phase with the run windings by more electrical degrees. A capacitor is used, causing the current in the start winding to reach its maximum value before the current in the run winding becomes maximum. Actually, the capacitor causes the current in the start winding to lead the current in the run winding. This causes a revolving magnetic field in the stator, which induces a current in the rotor and causes it to rotate. Remember, when the motor stops, the centrifugal switch contacts will close by spring pressure so that the motor can be started again. Capacitor-start motors are usually furnished in ratings from 1/6 to 1 hp and are used on compressors, pumps, fans, and machine tools.

*Permanent-split capacitor motors*. The permanent-split capacitor motor consists of a standard split-phase type stator, a squirrel-cage rotor, a capacitor, and endbells. This is another version of the basic split-phase motor. A permanent-type capacitor is connected in series with the start windings and left in the circuit at all times (see fig. 1-18). The start windings in this motor are not high-resistance windings and have the same number of turns and wire size as the run windings. The capacitor is used instead of resistance to give the split-phase effect. This eliminates the need for a centrifugal switch in this motor. The capacitor is continuously rated and is selected to give best operation at full speed while sacrificing starting torque. The permanent-split capacitor motor has the operating characteristics of poor starting torque with a high current draw. However, it runs with a good torque under load conditions and at a constant speed.

*Shaded pole motors*. The shaded-pole motor is a single-phase induction motor that uses a different method to produce starting torque. Instead of a separate winding like the the split-phase and capacitor motors, the shaded-pole motor's start winding consists of a copper band placed across one tip of each stator pole. See figure 1-19. This copper band has the characteristic of delaying the magnetic field through that portion of the pole. When AC power is applied, the main pole reaches its polarity before the shaded portion of the pole. This causes the shaded poles to be out of phase with the main poles, and a weak rotating magnetic field is produced. Due to the low starting torque, it is not feasible to build motors of this type larger than 1/20 hp.

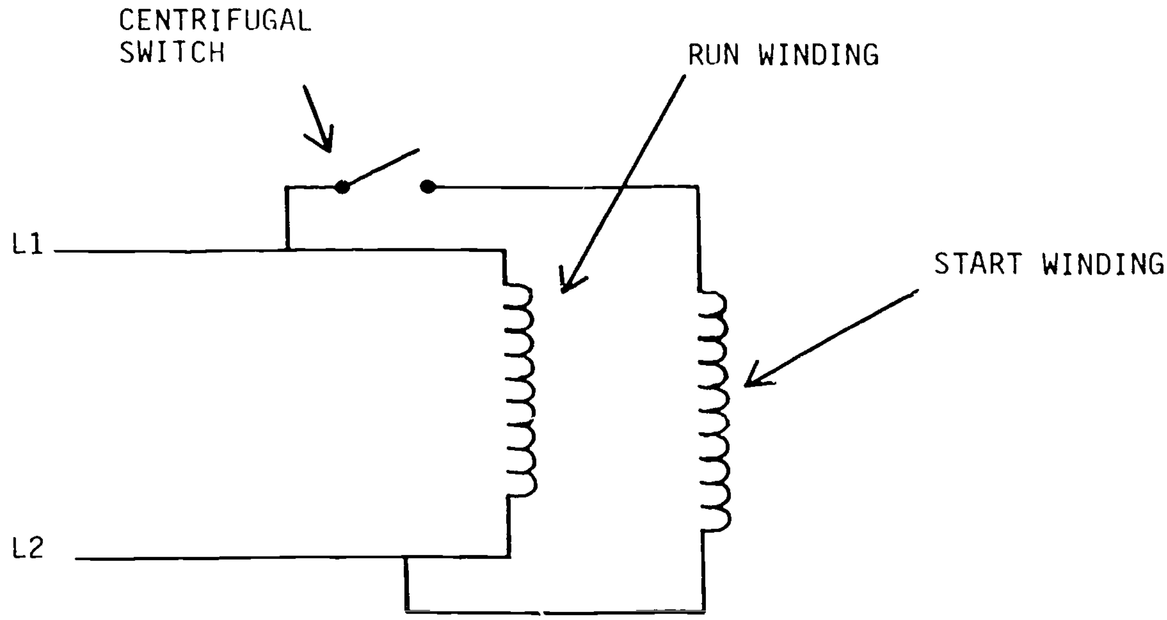


Figure 1-16. Split-phase motor schematic.

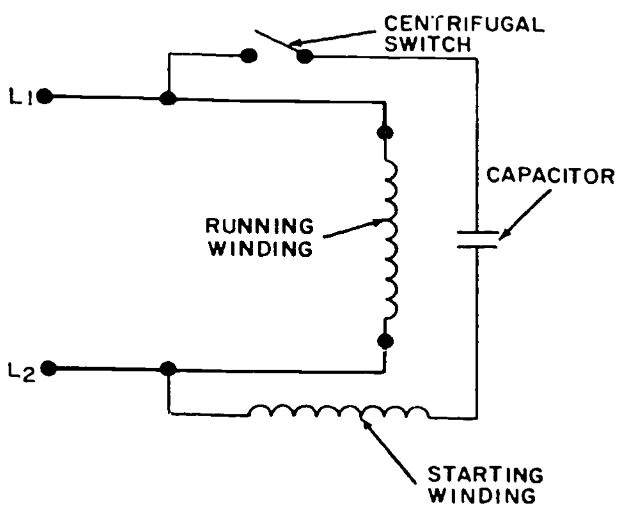


Figure 1-17. Capacitor-start motor schematic.

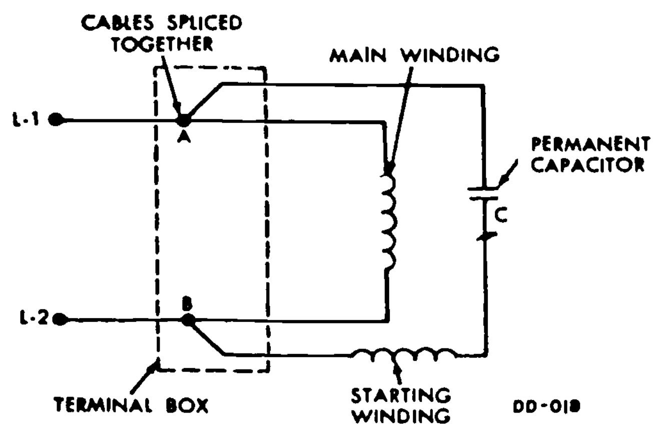


Figure 1-18. Permanent-split motor schematic.

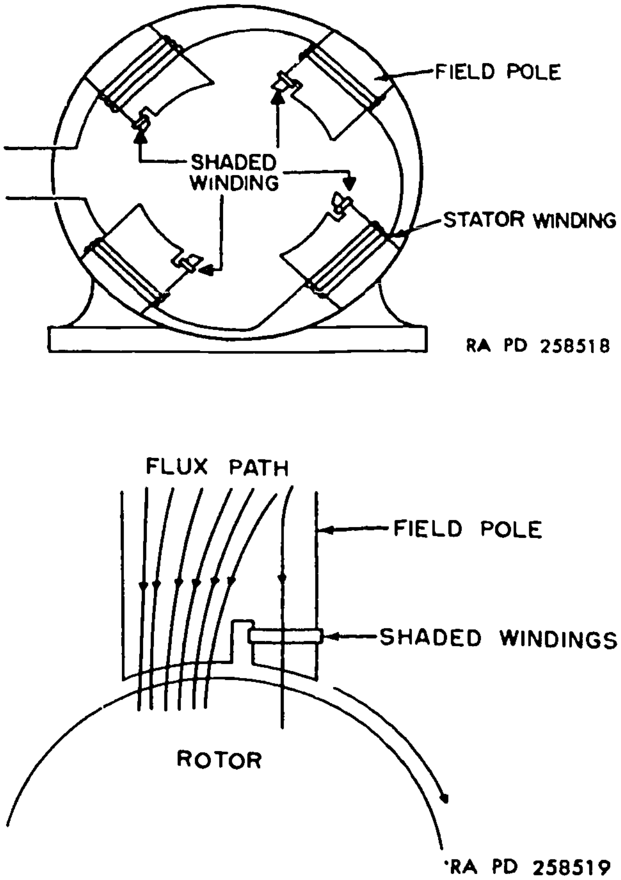


Figure 1–19. Shaded-pole stator.

They are used with small fans, timers, and various light-load control devices.

Remember all 1ϕ induction motors have some auxiliary means to provide the motor with starting torque. The methods used for this starting torque greatly depend on the application of the motor.

**Exercises (405):**

1. List the two windings found in a split-phase motor.

2. What is the purpose of the centrifugal switch in a split-phase motor?

3. How are the contacts of the centrifugal switch connected in relation to the start winding?

4. How is the addition of a capacitor in the start winding of a capacitor-start motor beneficial?

5. At what percentage of full speed will the centrifugal switch open?

6. What type of AC motor uses a capacitor in series in the start winding but no centrifugal switch?

7. In what devices are shaded-pole motors used?

8. What is the purpose of a shaded-pole in a shaded-pole motor?

**406. Describe the types and operation of single-phase AC commutator motors.**

**Types of 1ϕ Commutator Motors.** Single-phase commutator motors have a drum-wound armature, a commutator, and brushes. Of these, we will discuss the repulsion-type motors and the universal motor. let's start with the repulsion-type motors which are generally divided into three classes: (1) the repulsion motor, (2) repulsion -start induction-run motor, and (3) the repulsion-induction motor. The similarity of names sounds confusing, but each class is designed for different applications.

*Simple repulsion motors.* A simple repulsion motor consists of a single concentric-type stator, a wound rotor, a commutator, two carbon brushes, compensating windings, and endbells. See the schematic wiring diagram in figure 1-20. The stator windings and the compensating windings are connected in series. The compensating windings are used to improve the power factor in this motor. Two carbon

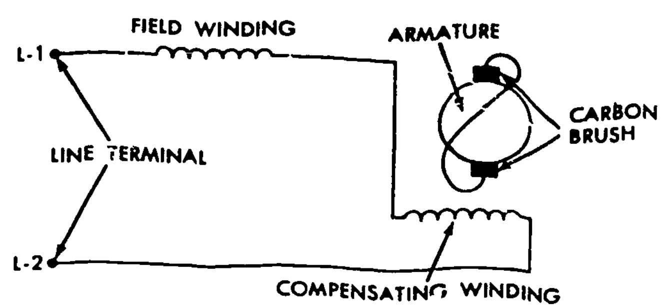


Figure 1–20. Simple repulsion motor schematic.

brushes are short circuited to each other. A simple repulsion motor has the operating characteristics of high starting torque and low starting current draw. Although its starting torque is useful, its large variation of speed with load is not desirable in many applications. This motor is commonly made in sizes from 1 to 10 hp and is used to power such loads as conveyors, small compressors, and woodworking equipment.

*Repulsion-start induction-run motors.* The repulsion-start induction-run motor consists of a single concentric-type stator, a wound rotor, compensating windings, a centrifugal device. and endbells. This type of repulsion motor uses four carbon brushes. Two are short circuited together; the other two brushes are connected in series with the compensating wind. The compensating windings in this motor are used to improve the power factor during the starting period.

The centrifugal device used in this motor consists of a shorting ring and a brush-lifting mechanism. As the motor reaches approximately 75 percent of its rated speed, the centrifugal device forces the short-circuiting ring into contact with the inner surface of the commutator segments and converts the motor into an induction motor. At the same time, the centrifugal mechanism raises the brushes, which reduces wear of the brushes and commutator. This motor has the operating characteristics of high starting torque with a low current draw and a constant running speed under load. The repulsion-start induction-run rotor, shown in figure 1-21, is made in sizes from 1/4 to 10 hp and is used to power such loads as compressors, fans, pumps, stokers, and farm machinery.

*Repulsion-induction motors.* The repulsion-induction motor consists of a single, concentric-type stator, a combination rotor, a commutator, brushes, compensating windings, and endbells. This type of motor has four carbon brushes. Two are short circuited together; the other two are in series with the sating windings. The compensating windings in this motor are used to improve the power factor of the motor and to reduce some of the sparking at the brushes. This motor does not have a centrifugal switch or device but instead has a squirrel-cage winding on its rotor in addition to a wound rotor. Rotors of this type are called combination rotors. The squirrel-cage winding is placed underneath the wound rotor section and is so constructed as to have high-inductive reactance. At low speeds, very little current flows in the squirrel-cage windings and the motor starts as a repulsion motor. When the motor reaches operating speed, the frequency of the induced rotor currents is low so that current flows more in the squirrel-cage winding and the motor operates as an induction motor. This motor has the operating characteristics of high starting torque with a low current draw and a constant running speed under load. The major disadvantage of this motor is that the brushes remain on the commutator, causing arcing, thus increasing maintenance. The type of repulsion-induction motor diagrammed in figure 1-22 is available up to 10 hp and is used to power such loads as printing presses, textile machines, and laundry extractors. To reverse the direction of rotation, the brushes must be shifted past the neutral plane.

*Universal motors.* A universal motor is one that can operate on either single-phase AC or DC power. These motors are normally made in sizes for special conditions. The fractional horsepower sizes are used on vacuum cleaners, sewing machines, food mixers, and power handtools. There are several types of universal motors; however, the salient-pole type is more popular than the other types.

The salient-pole type consists of a stator with two concentrated field windings, a wound rotor, a commutator, and brushes. The stator and rotor windings in this motor are connected in series with the power source. There are two carbon brushes in this motor that remain on the commutator at all times. These two brushes are used to connect the rotor windings in series with the field windings and the power source. See the schematic in figure 1-23.

The universal motor does not operate at a constant speed. The motor runs as fast as the load permits—low speed with a heavy load and high speed with a light load. Universal

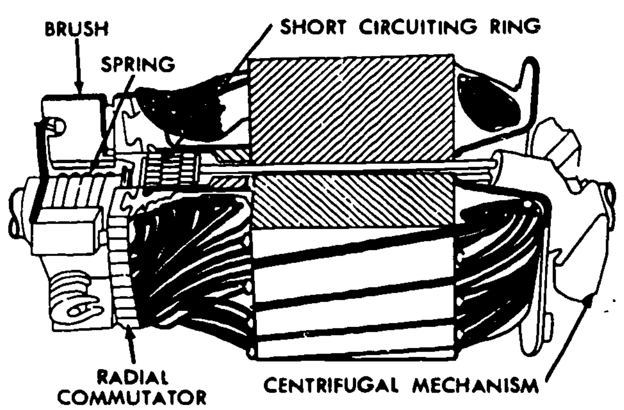


Figure 1–21. Repulsion-start induction-run rotor.

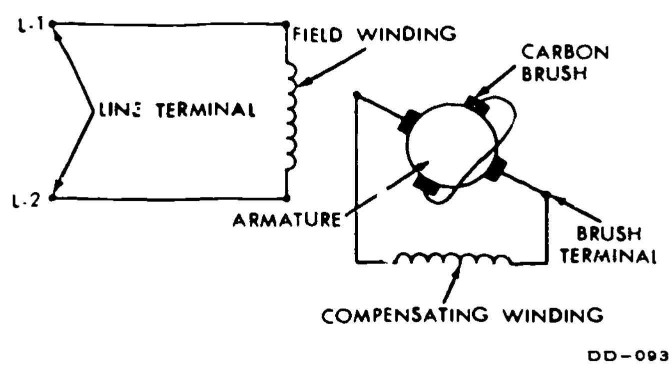


Figure 1–22. Single-phase repulsion-induction motor schematic.

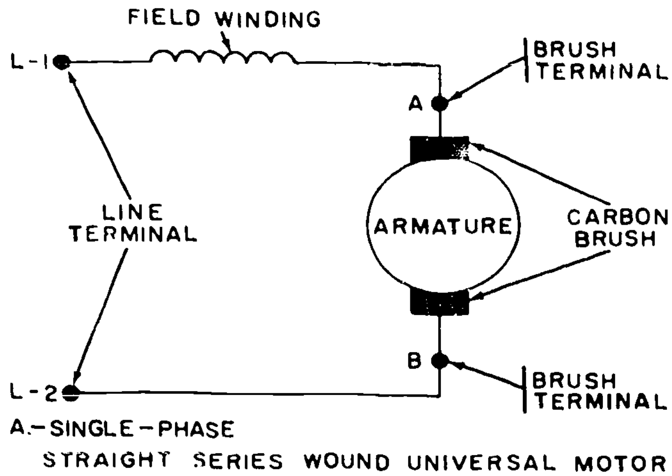


Figure 1–23 Universal motor schematic.

motors have the highest horsepower-to-weight ratio of all the types of electric motors.

The operation of a universal motor is .nuch like that of a series DC motor. Since the field winding and armature are connected in series, both the field winding and armature winding are energized when voltage is applied to the motor. Both windings produce magnetic fields which react to each other and cause the armature to rotate. The reaction between these magnetic fields is caused by either AC or DC power.

**Exercises (406):**

1. List the three kinds of repulsion-type commutator motors.

2. What are the operating characteristics of a simple repulsion motor?

3. Which type of repulsion motor would power conveyors, small compressors, and woodworking equipment?

4. What purpose do the compensating windings in a repulsion-start induction-run motor serve?

5. Why does a repulsion-induction motor start as a repulsion motor?

6. What causes a repulsion-induction motor to operate as an induction motor?

7. What factor determines the operating spe·d of a universal motor? Explain.

8. What type of motor can operate on either AC or DC power?

**407. State the procedures necessary for the connection of $1\phi$ AC motors.**

**Single-Phase AC Motor Connections.** Single-phase AC motors are manufactured for single-voltage or dual-voltage situations. They can also be reversible or nonreversible in operation. These $1\phi$ AC motors are usually made to operate on a common $1\phi$ AC voltage; for example, 120 volts, 208 volts, or 240 volts.

The single voltage, nonreversible-type AC motor will have only two leads, T1 and T2. The single voltage reversible motor will have four leads numbered T1, T2, T5 and T8. A dual-voltage nonreversible motor will have four leads numbered T1, T2, T3, and T4. The dual voltage reversible motor leads will be numbered T1, T2, T3, T4, T5, and T8. Leads numbered 6 and 7 are terminals of coils which are usually connected internally.

In order to operate a dual-voltage motor on high voltage, the run windings must be connected in series as shown in figure 1-24. Leads T1 and T2 go to one set of windings, while T3 and T4 go to another set. Connecting T2 and T3 together connects the run windings in series for 240-volt use. Connecting T1 and T3, and T2 and T4, as shown in figure 1-25, is connecting the motor for 120-volt operation. Figures 1-24 and 1-25 show no external terminal leads for the start winding because the connections are made internally. Therefore, this motor will be a dual-voltage nonreversible ty·e.

The start winding is always connected in parallel with the run winding, regardless of which voltage (high or low) is connected to the motor. Remember, the start winding cannot at any time have more than 120 volts across it. In a reversible type motor, le·ds T5 and T8 will be externally available in the terminal box. To change rotation of a 10 motor, we must change the direction of the current flow in the start winding in relation to the run winding. This can be done by interchanging leads T5 and T8, which will change the current flow in the start winding and reverse the rotating

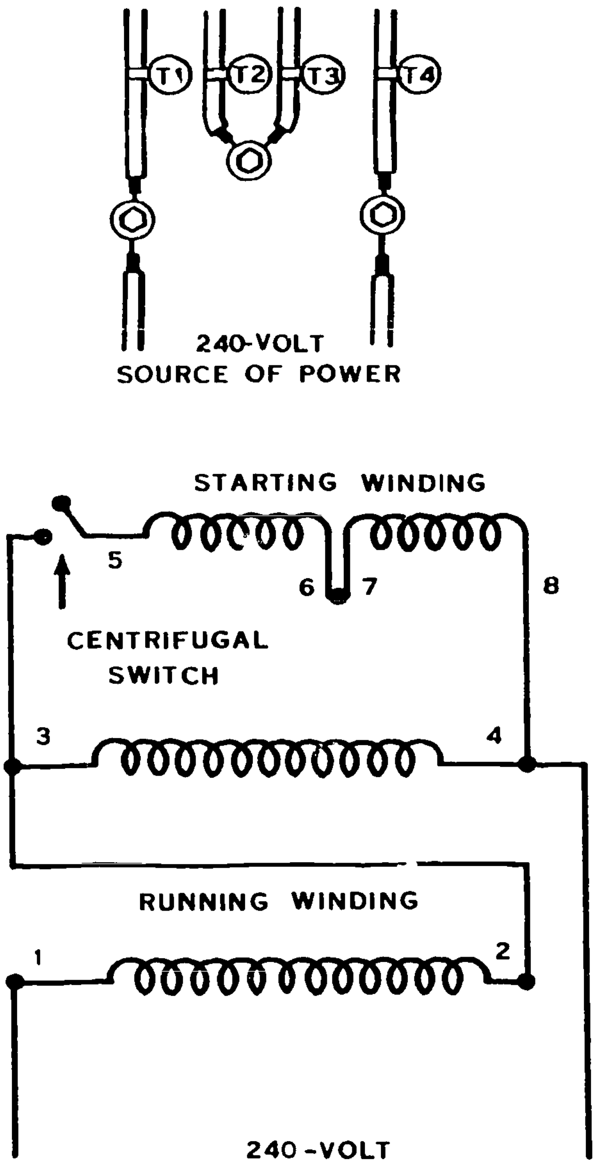


Figure 1–24. High-voltage connections.

magnetic field. Of course, you can do reversing procedures only when the start windings lead are externally available.

**Exercises (407):**

1. How many external leads are necessary for a single-voltage, nonreversible-type 1$\phi$ motor?

2. To connect a dual-voltage motor for high voltage, the run winding must be connected in ____________. (Series of parallel)

3. The start winding must always be connected in ____________ to the run windings.

4. What leads are reversed to change the rotation of a single-phase reversible induction motor?

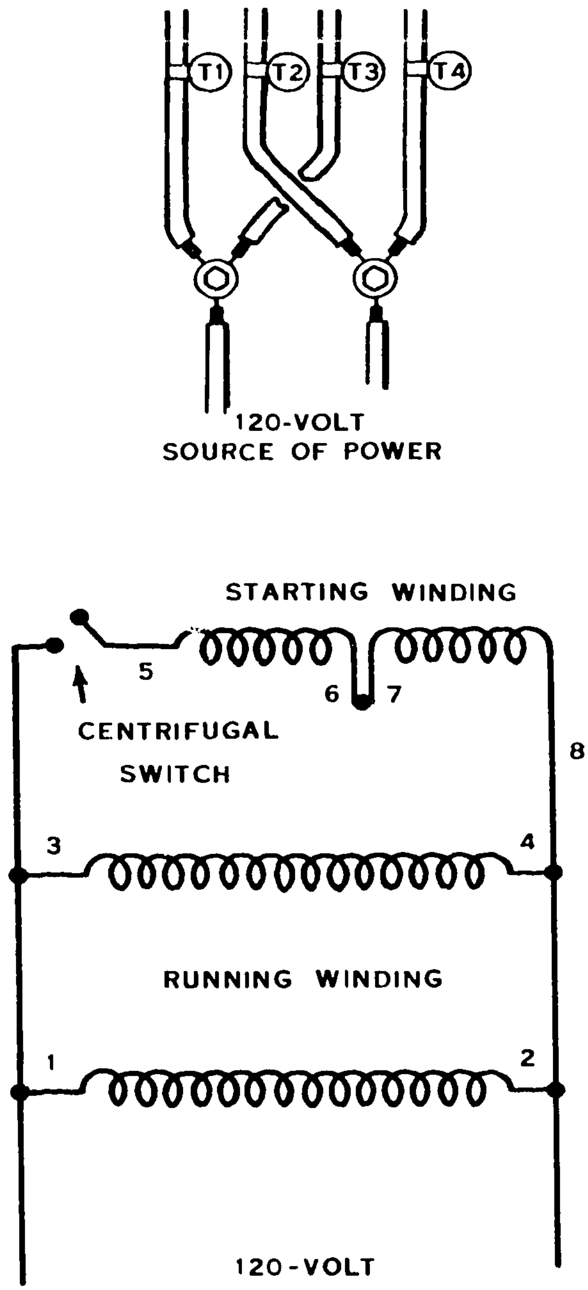


Figure 1–25. Low-voltage connections.

## 1-2. Motor Controls

In this section, we will discuss some of the common AC motor controllers. The term controller refers to any switch or device normally used to start and stop a motor. A controller can be very simple or very complex, depending on the situation. As an electrician, you will be responsible for insuring that motors and their controls are operating properly. In order to do this, you will need to understand how controls work.

**408. List the types of manual across-the-line motor controls and state how they operate.**

Across-the-line controls are devices which will start, stop, and usually protect a motor. To stop and start a motor, an across-the-line control must contain a device which will make and break contacts in the supply lines to the motor. In addition, the control will normally provide some form of motor current protection. Across-the-line AC motor controls are generally of two types: (1) manual or (2) magnetic.

**Manual Control.** A manual control is a device, either hand or mechanically operated, for controlling a motor from a single point. This is done by moving a switch or pushing a button. Each controller must be capable of starting and stopping the motor which it controls. The manual control can be a plain switch with or without overload protection. The term overload protection refers to a device sensitive to motor current. This device is designed to protect the motor windings by interrupting the current flow when an overload situation exists. Manual controllers can be used to control both 1ϕ and 3ϕ motors. They are generally limited to small horsepower applications.

*Toggle switches.* A toggle switch or light switch is usually used to control a small motor. It must be connected to open the ungrounded conductors in the circuit. To operate a 240-volt motor with two ungrounded conductors, you would use a double-pole switch to open both ungrounded (hot) conductors simultaneously. In a 120-volt circuit, only a single-pole switch is necessary to open the ungrounded conductor. A bathroom exhaust fan or garbage disposal operated by a toggle switch is a good example of this type of control. Remember, a toggle switch is limited to the size motor it can safely control. The motor is protected by a branch circuit overcurrent protection device, which is the circuit breaker.

*Fused Safety Switch.* The fused safety switch or disconnect switch can be used on small 1ϕ or 3ϕ motors. It operates on the same principle as the toggle switch. It must be connected to open all ungrounded (or hot) conductors to the motor.

*Pushbutton controllers.* The schematic for a manual pushbutton controller with overload protection is shown in figure 1-26. In this case, the controller is connected to a device which connects or disconnects both ungrounded conductors to the motor. It has a start and stop button that mechanically opens or closes the contacts. Pressing the start button closes both contacts and pressing the stop button opens both contacts. The control has two overload devices connected in series with the contacts. If an overload condition occurs, either overload device will open both sets of contacts. A typical application of this type of control would be to control small machine tools.

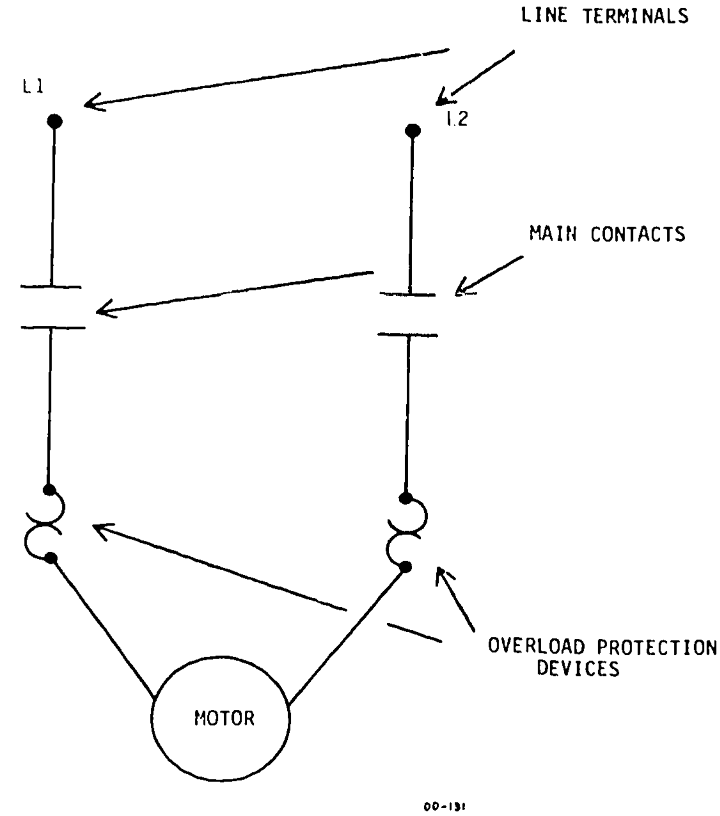


Figure 1–26. Schematic for a 1ϕ manual controller with overload protection.

*Three-phase manual controllers.* Manual controllers used to control 3ϕ motors have three separate line terminals, one for each ungrounded conductor. These three terminals are connected internally to three separate sets of main contacts which are used to manually open and close the circuit to the motor. When the controller has overload protection, it has an overload device installed in series with each main set of contacts. The overload devices respond to an overload condition by opening all main contacts and disconnecting the motor, the same as the pushbutton controller did.

The three line terminals are usually labeled L1, L2, and L3. These terminals are points at which the supply conductors are attached. The three load terminals are usually labeled T1, T2, and T3 and are the points where the conductors supplying the motor are attached.

*Drum control.* The drum control is a manual control normally used to change the rotation of a motor. The drum control is a lever-operated, three-position switch. The center position is usually the off position with the right and left positions forward and reverse respectively. Figure 1-27 shows a schematic of a 3ϕ drum control with its internal contacts. You can see in the right half of the figure that the L1 contact feeds motor lead T1. L2 feeds motor lead T2 and

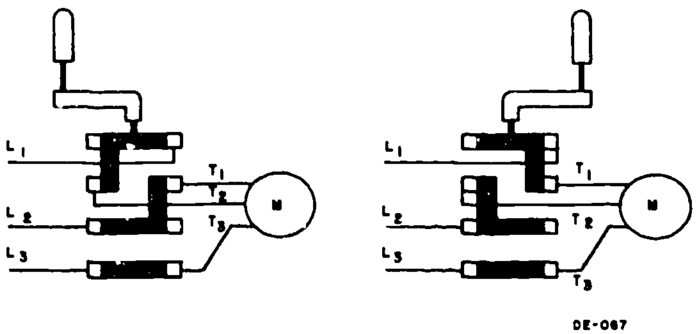


Figure 1–27. Reverse and forward drum control positions.

L3 feeds motor lead T3. On the left side of the figure, L1 and L2 have reversed their respective motor lead contacts. L3 is still feeding T3. What we have done is reversed 2 power leads to our motor.

A 1ϕ motor can utilize the same drum control, but four or five conductors are required from the motor to the control, depending on the requirement for high or low voltage operation. Always refer to the cover of the control for a schematic of the connections required for a specific motor installation.

All normal controllers have two basic characteristics:

*a*. When activated, they will energize the motor circuit until they are normally deenergized.

*b*. When an overload occurs in the motor circuit, the circuit protection should open or the built-in overload contacts should open.

**Exercises (408):**

1. List the two types of across-the-line AC motor controls.

2. What is a manual motor-control device?

3. How are the overload devices connected in a three-phase manual controller?

4. The manual pushbutton controller has ____________ ____________ to react to excess motor current.

5. The three line terminals of a 3ϕ manual controller are labeled in what manner?

6. What is the purpose of the drum control?

**409. Name and state the purpose of the parts of a magnetic control, and give specific details about selecting heaters for motors.**

**Magnetic Controls.** Another across-the-line motor-control device that you can use is the magnetic control. This control, or starter, is operated magnetically and connects the motor across the line using an electromagnet to close the main or load contacts. This type of starter provides a safe, convenient, and economical means for controlling an electric motor. Magnetic controls are the most commonly used starters and offer the advantage of being controllable with an automatic device or a remote control. A magnetic control, commonly called an across-the-line magnetic starter, consists of two main sections: the contactor and the overload relay.

*The contactor*. The contactor consists of the following parts: an operating (or holding) coil and armature, main and auxiliary contacts, and terminals. The coil is the stationary portion of the contactor and uses a laminated iron core and a winding to produce an electromagnetic effect. The armature is the movable portion of the contactor which is attracted to the operating coil when the coil is energized. One side of the main contacts are connected to the armature, and the other side of the main contacts are stationary. When the electromagnetic coil is energized, it sets up a magnetic field attracting the armature. This closes the main or load contacts and completes the circuit, thus starting the motor. Shaded rings are placed on the stationary core to provide a time delay in the loss of flux, thus preventing contact chatter and wear in the moving parts of AC magnetic starters. Figure 1-28 shows a line drawing of the basic parts of a magnetic contactor.

The auxiliary contacts or holding contacts are also located on the contactor. They are usually joined by an insulated connecting bar so that all contacts, both main and auxiliary, will close when the holding coil becomes energized.

The contactor also provides terminals for the attachment of the supply conductors. These terminals usually are identified with the letter "L". For example, terminals L1 and L2 are the supply conductor terminals of a 1ϕ magnetic starter. The auxiliary contacts also have terminals. Auxiliary terminals are used to attach the conductors from control devices and are identified with the numbers 2 and 3. Auxiliary contacts will be discussed in more detail later.

*Overload relay.* Nearly all magnetic starters are equipped with an overload device or overload relay to protect the motor from excessive current in a running situation. Current-sensitive elements of the overload relay are connected either directly or indirectly and act to

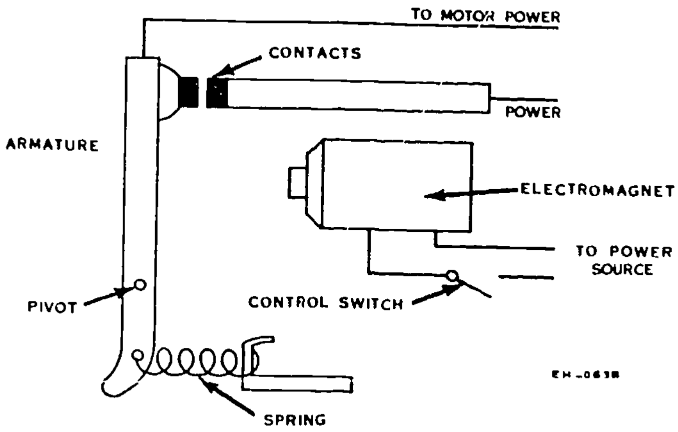


Figure 1–28. Magnetic contactor.

deenergize the starter and stop the motor when excessive current is drawn.

The basic requirement for overload protection is that the motor be allowed to carry its full-rated load and yet prevent any prolonged or serious overload. When a motor is overloaded mechanically, motor current increases, which in turn increases the temperature of the motor and its windings. The same increases in current and temperature are caused by the loss of one phase on 3ϕ motors, or a partial fault in the motor windings. Therefore, to give full over-load protection, we need only to sense, or measure, the current draw by the motor and break the circuit when this current exceeds the rated value for the motor.

There are two basic types of overload relays, thermal and magnetic. The first is a unit which is sensitive to heat. This unit may be a bimetallic type or melting-alloy type. The second type uses a magnetic device and is sensitive to motor current. (The principle involved is the same as that for thermal and magnetic circuit breakers covered in Volume 2.)

Regardless of which type of device is used, it is activated by an excessive current flow in the motor. When one of these devices detects an excessive current, it will react by opening a set of reset contacts which are in series with the holding coil. This causes the holding coil to deenergize and open the main or load contacts.

Overload relays must be reset after each tripping, either automatically or manually. The automatic reset type should not be used except on equipment that is so designed that there can be no danger to life or equipment from the restarting of the motor.

To better understand the overload relay, let's look at each type individually.

*a.* Thermal overload relays. Thermal relays are usually of the bimetallic or melting alloy types. The bimetallic type is constructed of two dissimilar metals which, when heated, bend due to the different rate of expansion of the two metals. A heating element in the motor-line circuit generates the heat necessary to activate the strip. Current in excess of the desired amount causes deflection of the bimetallic strip to the extent that the contacts spring apart, thus opening the holding coil circuit. Figure 1-29 is a line drawing of bimetallic overload relay. A reset button is depressed to reactivate the mechanism when the strip has cooled to operating tolerance.

The melting-alloy overload relay employs a heating coil connected in the motor-line circuit. See figure 1-30. The heat caused by excessive current in the motor circuit melts the metal alloy (similar to solder) releasing the spring-loaded shaft. The shaft is then capable of turning. This permits the reset contacts to open, thereby disrupting service to the motor. When the alloy has cooled and solidified sufficiently, the motor may be restarted by depressing the reset button. A laboratory example of the melting alloy principle is shown in figure 1-30. The main advantage of the melting-alloy relay over the bimetallic type that is its amperage rating doesn't vary after repeated heatings.

*b.* Magnetic overload relays. The magnetic overload relay consists of a coil, a plunger, a dashpot, and a set of contacts. See figure 1-31. The coil is connected in series with the motor. When a determined amount of current passes through the coil, the magnetic field will pull the plunger up, causing the contacts to open. By adjusting the length of the plunger, the amount of current required to pull the plunger up can be varied. An oil-filled dashpot is added to provide a time delay. A plate on the bottom of the plunger is submerged in the oil and acts as a piston. The plate has holes in it that can be adjusted in size to change the time delay. When the coil pulls the plunger up, the oil must flow through the hole in the plate as the plunger rises. By changing the size of the hole, the time delay can be increased or decreased. Quick tripping is obtained through the use of a light grade dashpot oil.

**Selecting Heaters.** The overload relay size is determined by the full-load current of the motor it protects. When selecting the heaters to protect a motor, you should check the motor data plate to find the full-load current. Each manufacturer normally puts a heater selection table in the controller cover. Heaters are not identified by amperage, but by the manufacturer's catalog number. By using the full-load current of the motor and referring to the manufacturer's table, the proper heater can be selected.

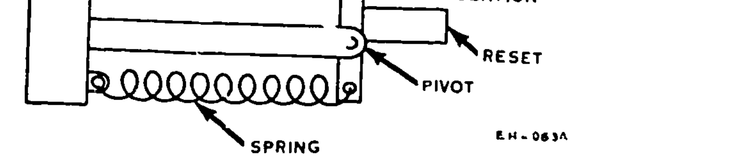


Figure 1–29. Bimetallic overload relay.

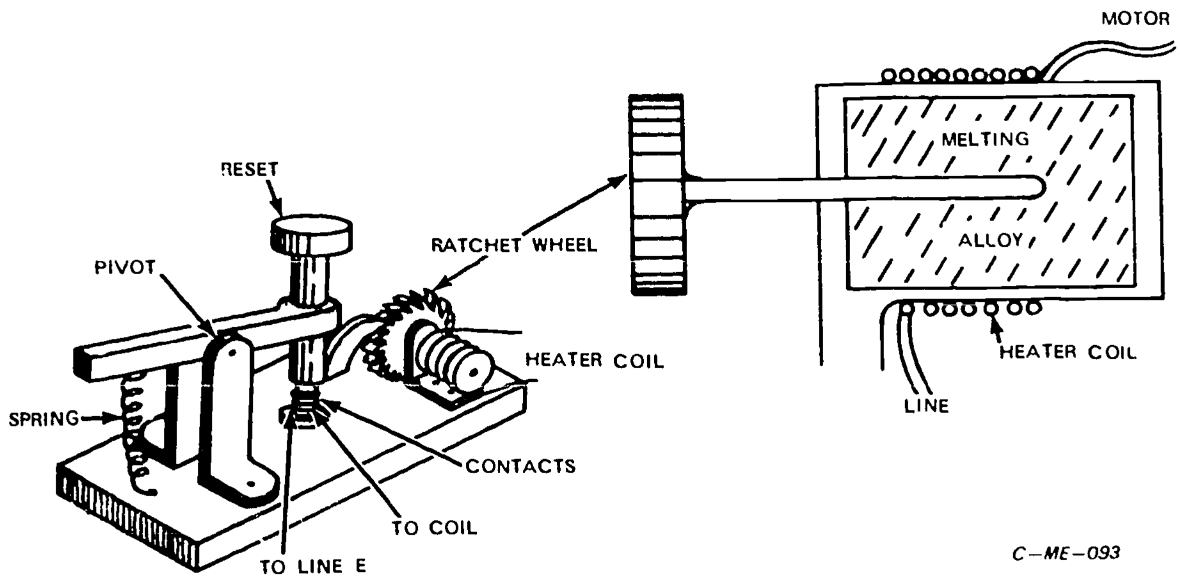


Figure 1–30. Melting-alloy thermal overload relay.

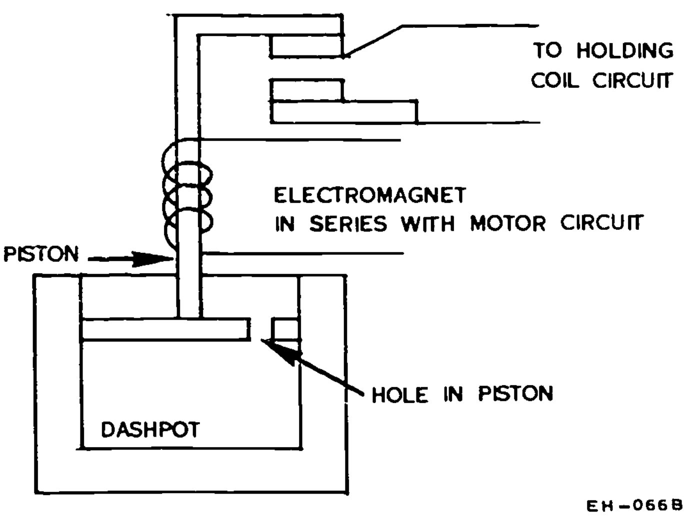


Figure 1–31. Magnetic overload relay.

The overload relay also provides terminals for the attachment of the supply conductors. These terminals usually are identified with the letter "T." For example, terminals T1 and T2 are the load terminals of a single-phase magnetic starter and provide a point to connect the conductors supplying the motor.

**Exercises (409):**

1. What are the two main parts of an across-the-line magnetic starter?

2. What part of the contractor attracts the armature?

3. What is the purpose of the shaded ring on the stationary core of the armature?

4. List the two basic types of overload relays.

5. What are the two basic types of thermal overload relays?

6. How can you find the full load current rating of a motor?

**410. State selected details of the operation of magnetic across-the-line motor controls.**

**Operation.** The operation of an across-the-line magnetic starter is fairly simple. When the electromagnetic coil is energized, it sets up a magnetic field attracting the armature. When the armature moves toward the electromagnet, the movable contact connects with the stationary contact. This completes the circuit to the motor and the motor starts. When the switch in the circuit which supplies power for the electromagnetic coil is opened, the coil is deenergized, causing a loss of the magnetic force and causing the spring to pull the contacts apart. Other magnetic line starters will have more contacts and motor overcurrent-protection relays and may depend on gravity to open the contacts.

The across-the-line magnetic starter contains two electrical circuits: the load circuit and the control circuit. The load circuit contains the main or load contacts, the line terminals, load terminals, and the heater coil portion of the overload relay. The load circuit is the determining factor as to the size of motor it will control. It must have a larger rating than the connected motor. The control circuit contains the holding coil, reset contacts of the overload relay, and the auxiliary contacts. The control circuit is the portion of the magnetic starter that performs the function of starting, stopping, controlling, and protecting a motor. In addition to the starter control circuit itself, some type of control unit, generally called an accessory, must be used to open and close the application of power to the operating coil. These devices will generally be connected using a two- or three-wire circuit.

A two-wire control circuit receives its power from the incoming leads to the starter. The basic control circuit is a series circuit from L1, going through the control device, the holding coil, and the overload reset contacts, and returning to L2 or to neutral, depending on the voltage rating of the coil. Figure 1-32 shows a diagram of a two- wire control circuit using a single-pole toggle switch as a control device. The magnetic coil is connected to the line on one side through the overload reset contacts and on the other side through the contacts of the toggle switch. As long as the contact of the toggle switch remains closed, the contactor will be energized. When the contacts of the toggle switch open, the coil will be deenergized and the contactor itself will open. Notice that when an overload occurs, the overload relay reset contacts will open and this will remove the holding coil from the circuit. When the overload relay is reset, the contactor will again immediately pick up because the toggle switch is in the closed position.

A three-wire control circuit also receives its power from the incoming leads to the starter. This circuit uses the same components as the two-wire circuit, except that the auxiliary contacts and a stop-start station are introduced. Remember, the auxiliary contacts are controlled by the holding coil, and close and open at the same time as the main contacts. The stop-start station is a manual control device containing a start and stop button. When the start button is pressed, a normally open set of contacts is closed; and when the stop button is pressed, a normally closed set of contacts is opened. Spring action returns the buttons to their original position when finger pressure is removed. To operate a magnetic starter by a stop-start station, it is necessary to connect the holding coil to the stop-start station so that, when the start button is pressed, the coil will become energized and, when the stop button is pressed, the holding coil circuit is opened.

A diagram of a typical across-the-line magnetic starter equipped with two thermal overload relays and connected to a stop-start pushbutton station is presented in figure 1-33. When the start button of the station is pressed, it completes the circuit from L1 through the normally closed contacts of the overload relays and through the holding coil to L2. Thus, the coil is energized and the main contacts are closed, connecting the motor across the line. This action also closes the auxiliary contacts, which keep the holding coil energized after the finger is removed from the start button.

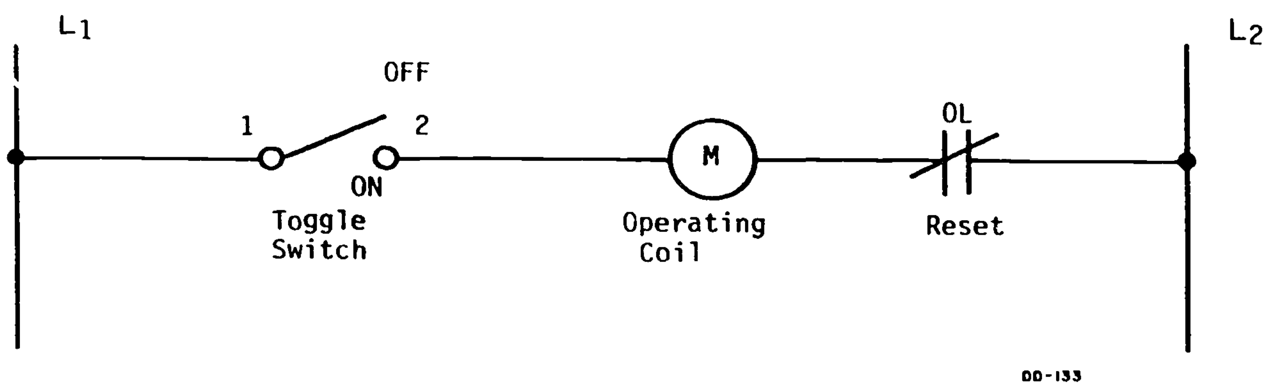


Figure 1-32. Two-wire control circuit.

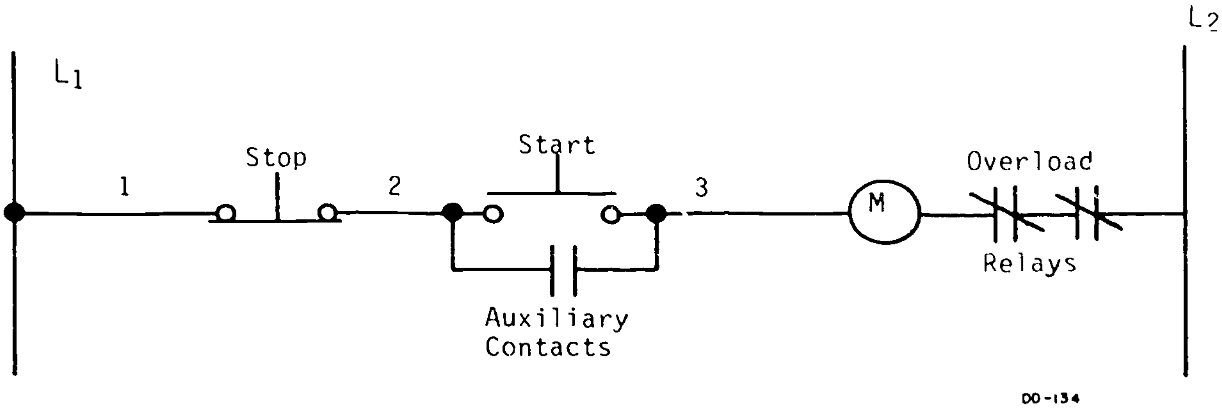


Figure 1–33. Three-wire control circuit.

Pressing the stop button opens the control circuit and causes all contacts to open. If a prolonged overload should occur during the operation of the motor, the overload relay contacts will open and deenergize the holding coil. If an overload condition has caused the relay to trip, it will be necessary to reset the relay contacts by hand before the motor can be restarted.

*Single-phase controller*. In order to control a 1φ motor, a 1φ across-the-line magnetic starter must be used. The 1φ starter must have line terminals L1 and L2 for the connection of the (line) conductors and T1 and T2 for the connection of the motor (load) conductors. A motor-running overload protection device, such as an overload relay, thermal or magnetic, must be installed. In accordance with the National Electrical Code (NEC), there must be one overload device installed in either ungrounded conductor for a 1φ AC motor. For example, a 208-volt two-wire 1φ system has two ungrounded conductors attached to L1 and L2. One overload device must be installed in series with each one of these ungrounded conductors. Figure 1-34 shows a diagram of a 1φ across-the-line magnetic starter.

*Three-phase controller*. In order to control a 3φ motor, a 3φ across the line magnetic starter must be used. The 3φ starter will have line terminals L1, L2, and L3 for the connection of the line conductors and T1, T2, and T3 for the connection of the motor load conductors. Like the 1φ controller, the 3φ magnetic starter must also have an overload relay with thermal or magnetic cutouts. The NEC requires that one of the previously mentioned overload devices be installed in each ungrounded phase of the starter. For example, a 208-volt three-wire 3φ system must have an overload device in each ungrounded phase, which means there would be three devices. Figure 1-35 shows a diagram of a 3φ across-the-line magnetic starter.

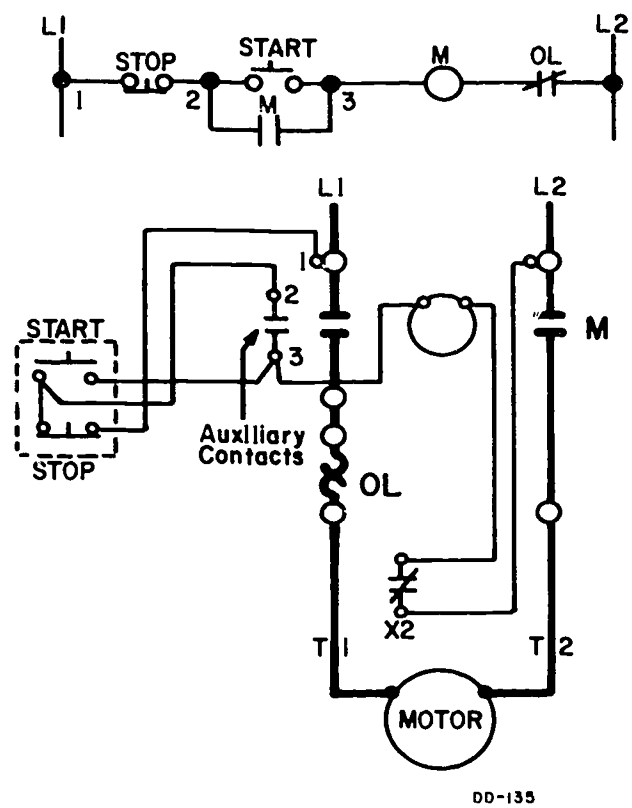


Figure 1–34. Single-phase across-the-line magnetic starter.

*Automatic controls*. Automatic devices can be used to control or operate a magnetic starter. They would be installed the same as the toggle switch in figure 1-33. Some of the most common types are:

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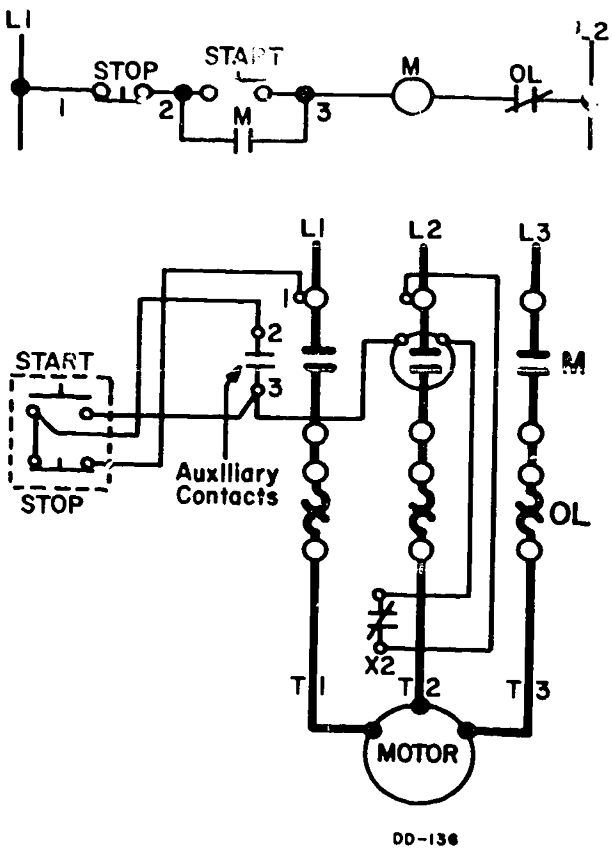



Figure 1–35. Three-phase across-the-line magnetic starter.

*a.* Float switches—Fluid levels are often controlled by the use of a float switch. This switch is a set of contacts which are opened or closed mechanically by a lever and float assembly. By using motor-driven pumps controlled by a float switch, the level of liquid can be increased or decreased automatically. An example of a common use of float switches is to control the water level in water towers.

*b.* Pressure switches—Pressure switches are used to control the pressure of gases, air, and liquids within a desired range. For example, a motor on an air compressor is controlled by a pressure switch.

*c.* Thermostats—The thermostat is a device sensitive to temperature and is widely used in heating and cooling systems to control the system.

*d.* d. Photoelectric Cells—The photoelectric cell is sensitive to light and is used widely to turn on and turn off exterior lights, such as street lights.

**Exercises (410):**

1. List the two electrical circuits of the across-the-line magnetic starter.

2. What set of contacts is used to keep the holding coil energized after the start button has been released?

3. How many overload relays must be installed on a 3$\phi$ magnetic starter?

4. List four automatic devices used to control magnetic starters.

5. What is the function of the control circuit in a magnetic starter?

## 1-2 Installation of Motors and Controls

The most expensive and elaborate motor system is worthless unless it is selected to meet specific requirements for a situation. It also must be installed correctly to perform these requirements. As an electrician, you should be able to determine the correct type of motor for a particular job and have the knowledge to correctly install the system according to the NEC.

**411. Restate specific factors to consider in selecting a motor and motor controller, and list the information required on a motor data plate.**

**Motor Selection.** Before you can install a motor, many factors need to be considered if trouble-free operation is to be expected.

*Physical location.* The physical location of the motor will affect the type of motor housing (inclosure) required. A different type motor inclosure is required to protect a motor that is exposed to rain as compared to one installed in a dry location. Insuring the proper selection will provide a trouble-free installation. Some of the common motor inclosures used for different environmental conditions are:

*a.* Open—An open motor has ventilating openings in the frame which permit the passage of cooling outside air over and around the windings.

*b.* Splash-proof—A splash-proof motor is an open motor in which the vent slots are made to prevent liquids or solids from entering them except at indirect angles.

*c.* Totally inclosed—This motor is built to prevent free passage of outside air. It is not airtight; therefore, it cannot be used in an explosive area.

*d.* Drip-proof—A drip-proof motor is an open motor in which the ventilating openings are constructed so that drops of liquids or solid particles falling on the machine, either directly or by striking and running along a horizontal surface, will not enter the motor.

*e.* Water-proof—A water-proof motor is a totally inclosed motor constructed so that it will prevent water

from entering even if applied in the form of a stream from a hose.

*f.* Explosion-proof—Explosion motors are designed to withstand an internal explosion of the vapors or dust from the area in which they are used and to prevent an explosion due to motor faults.

*Ambient temperature.* Along with the type of inclosure you select, you must consider the ambient (surrounding) temperature. The ambient temperature must not exceed that listed on the motor. In general, maximum ambient temperature is 40° C. or 104° F. for any motor, unless the motor is designed for a different degree rating.

*Duty.* Another important factor to consider when selecting a motor is its function or duty. Is the motor expected to run continuously or intermittently? A continuous-duty motor is designed to operate at full load for 24 hours a day if necessary. The intermittent duty motor is designed for frequent starting and stopping. It has construction features built in that will dissipate heat rapidly. This is an important factor in the selection of motors, since motor windings heat rapidly during starting.

*Bearings.* The types of bearings used in a motor usually depend on its application to a load or on its mounting plane, whether horizontal or vertical. As a general rule, sleeve-bearing motors are horizontally mounted and ball- or roller-bearing motors are designed for vertical or horizontal mounting.

*Voltage.* The voltage available to the motor must be considered when selecting a motor. The power supply must have the required phases and voltage to run the size motor available.

*Mechanical connection to load.* The connection between the motor shaft and the load that it drives is made in different ways, depending on the load. The most common methods for attaching the shaft to the load are by using pulleys, couplings, and gears.

*Motor data plate.* According to the NEC, every motor must be equipped with a data plate as shown in figure 1-36. This data plate must be marked with certain information pertinent to the motor. This information is necessary in determining circuit requirements for installing motors. Listed below, in no specific order, is the information required on a motor data plate:

*a.* Maker's name.

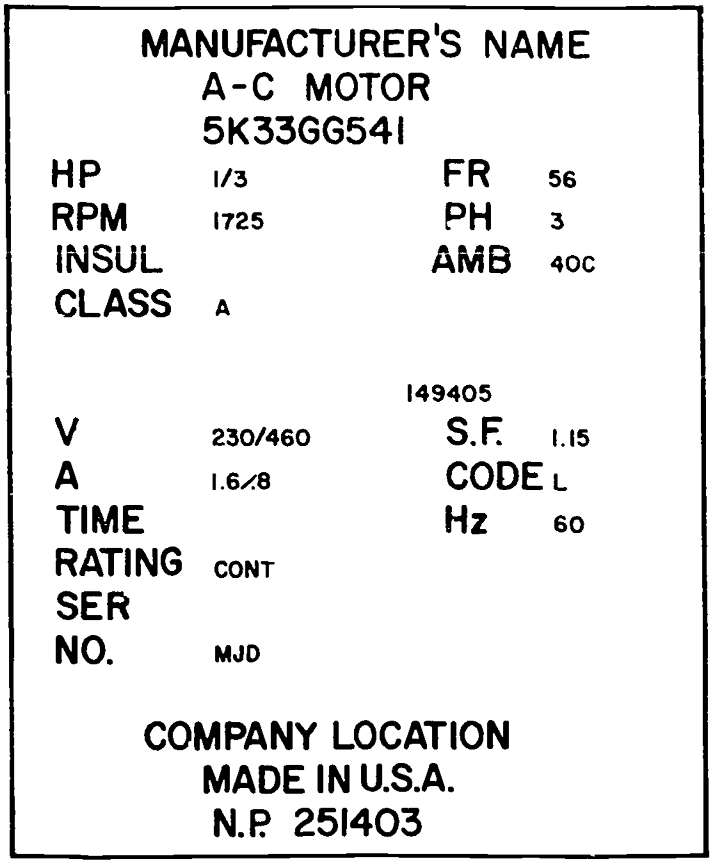
*b.* Rated volts and full-load amperes (amps). These show the motor's operating voltage and the current the motor will draw under full load. These are normally expressed as V for volts and A for amps.

*c.* Rated frequency and number of phases. These show the motor's operating frequency (marked) as hertz (Hz) and the required phases to operate the motor (marked) as (pH).

*d.* Rated temperature rise of the insulation system and rated ambient temperature. This is the motor's maximum operating temperature under normal conditions. This is normally listed on a motor data plate as rise 40° C. or Amb 40° C.

*e.* Rated full-load speed. THis shows the rpm of a motor under full-load condition. For example, rpm—1725.

*f.* Time rating. This tells if the motor is a continuous or intermittent type.




DC-48

Figure 1-36. Motor data plate.

*g.* Code letter. The code letter is used for determining branch circuit overcurrent protection by using table 430-152 of the NEC. Code L is shown in figure 1-36.

*h.* Rated hp (if 1/8 or more). This is used to determine circuit switch sizes; for example, hp 1/3.

Along with required information, some manufacturers furnish data plates with useful information, such as the frame number and service factor.

The frame number gives the physical dimensions of a motor; for example, shaft size, mounting configuration, keyway size, and the overall dimensions of a motor. Frame numbers are standardized, regardless of manufacture. This information is shown on the data plate as frame or FR.

The service factor is the amount of overload a motor can safely carry without damage to the unit. This is determined by multiplying the normal hp by the service factor. For example, a 1/3 hp motor with a service factor of 1.15 can be used to carry a continuous load of .38 hp (1/3 × 1.15). The normal service factors of most motors is 1.15. This information is found on the motor data plate, normally expressed as SF.

**Controller Selection.** Now that you have selected the motor for a specific job, the motor controller and related equipment must comply with the same requirements. If the motor inclosure must be explosion-proof, then the

controller, when installed under the same conditions, must be explosion-proof. The inclosure must be adequate for the location in which it is installed. The National Electric Manufacturer's Association (NEMA) has assigned inclosure numbers to identify the types of inclosures for controllers as follows:

| | | | | |
|---|---|---|---|---|
| *a*. | Type | 1 | - | open or general purpose. |
| *b*. | Type | 3 | - | weather protected. |
| *c*. | Type | 4 | - | moisture protected. |
| *d*. | Type | 7 | - | hazardous vaporproof. |
| *e*. | Type | 9 | - | hazardous dustproof. |
| *f*. | Type | 7 & 9 | - | hazardous vapor and dustproof. |
| *g*. | Type | 11 | - | oil emerged. |
| *h*. | Type | 12 | - | oiltight, dusttight. |

Any additional information you need might be found in Article 430 of the NEC, entitled "Motors, Motor Circuits, and Controllers."

**Exercises (411):**

1. To insure trouble-free operation list seven factors you should consider when selecting a motor.

2. Wha. type of motor inclosure is designed to prevent liquids or solids from entering it, except at indirect angles?

3. What is the most commonly found ambient temperature rise of a motor?

4. What type of bearings would you find on an electric motor mounted in a vertical position?

5. List the eight items found on the data plate of an electric motor.

6. A "type 3" motor controller is used in what type of location?

## 1-4. Inspection and Maintenance of Motors and Controls

To insure proper service and long life, a motor system requires proper inspection and maintenance. After a motor system is installed, it is expected to remain in service for some that time. To insure the motor system has a long life, a preventive maintenance and inspection program should be established. In a well-planned program, your maintenance is a system of routines designed to keep the system in satisfactory operating conditions through periodic inspections, cleaning, adjusting, and lubrication.

**412. Restate the proper procedures for inspection and maintenance of motors and controls.**

**Inspection of Motors.** A good inspection will often give advance notice to potential troubles. At frequent intervals, electric motors should be inspected. When performing these inspections, your senses can provide a means of identifying abnormal conditions. For example, your sense of touch can identify excessive vibration and temperature.

A good visual inspection of a motor should include checking for excessive wear, such as uneven wear of gears, sprockets, and couplings. Belts and pulleys should be checked for proper alignment and tension. Their surface condition must be observed to insure that no cracks, frayed edges, or excessive wear exists. Check the bearing area for evidence of vibration, any unusual noise, and excessive temperature.

**Preventive Maintenance of Motors.** You must check and maintain an electric motor just like any other piece of mechanical equipment. With proper servicing, a motor will last longer and give more efficient service. A few maintenance services are listed below.

*Cleanliness*. Inspect motors internally and externally for foreign materials such as dust, dirt, corrosion, and paint. Open-frame motors may be blown out with compressed air. You should not apply too many coats of paint to motors, because the thickness of the coats of paint will interfere with heat dissipation.

CAUTION: Air pressure used for cleaning should not exceed 25 pounds per square inch (psi) nozzle pressure. Excessive pressure can damage the insulation on the windings.

Wipe all excess dirt, grease, and oil from the surfaces of a motor with a cloth moistened with an approved Air Force solvent.

WARNING: Never use flammable or toxic solvents for cleaning motors. They may cause injury to personnel or damage to equipment. Also instruct your workers to use the solvent sparingly. It may soak into inaccessible places, and evaporation may be delayed long enough to soften and harm the insulation.

*Ventilation*. Check the running temperature of all motors. If the motor temperature is hotter than that specified on the nameplate, you must diagnose the trouble. The usual procedure for diagnosing motor overheating is to check the motor for restricted ventilation. Inspect the area around the motor for any obstruction which could hamper free air circulation. If air circulation is not hampered in any

way and the motor continues to run hot, reduce the load on the motor or use a motor with more power capability.

*Lubrication*. You should lubricate each motor according to the manufacturer's lubrication instructions. Improper lubrication causes motor bearings to overheat and eventually causes bearing failure. Check a motor for signs of grease and oil-seal failure. If an inside seal fails, the lubricant can get into the motor windings and deteriorate the insulation. This condition will let dust adhere to the windings and restrict air circulation. When air circulation is restricted, the motor windings will heat.

Inadequate lubrication causes the bearings to wear excessively and, eventually, to seize. When you lubricate a motor, refer to the manufacturer's manual to determine the type of lubrication required. Some motors require lubrication with oil, while others require grease. Many motor bearings are lubricated and sealed at the factory. The lubricant in these bearings usually lasts the life of the bearings.

**Preventive Maintenance of Motor Controllers.** You should inspect and service control equipment on the same maintenance schedule as motors. Motor starters can generally be repaired at the time of inspection on the job site.

*Contacts*. Check the contacts to insure a good electrical connection. When contacts open and close, the rolling and rubbing action keeps the contacts bright and clean; but infrequently operated contacts, or contacts under heavy load, develop overheating and create oxidation on the contacts. Copper oxidation on contacts is a poor conductor and must be removed. You may use a fine file or light sandpaper, but never use an emery cloth. Silver oxide forms on silver contacts and presents a black, dirty appearance. Although these contacts appear dirty, they seldom need cleaning.

The closed pressure of contacts is an important factor in their ability to carry current. A small contact with suitable contact pressure carries more current than a larger one with little or no pressure. Thin contacts are replaced because they lose their contact pressure with wear. You must keep contact springs in good condition. Replace them when they have been damaged or have lost temper by exposure to high temperatures.

*Connections*. Connections should always be clean and tight. Loose connections result in overheated parts that eventually must be replaced. Periodic inspection is necessary because temperature changes, vibration, and carelessness may loosen connections. Check all wiring for discoloration, which indicates high temperature or loose connections. In some cases, you will need to replace the wire after you have corrected the cause of the trouble.

*Movable core*. Inspect the movable core in a controller for cleanliness. Accumulated gum and dirt cause sluggish mechanical action that impairs the opening and closing of the contact. The mechanical linkage is designed to require no lubrication.

Noise results if the movable and stationary pole pieces do not fit together well when the contactor is closed and when dirt or rust prevents proper closure. The most prominent noise produced in a starter comes from a broken shaded pole (which is the single turn of wire or strap) imbedded in part of the laminated magnetic structure.

*Cabinet*. Check the cabinet housing the controller for cleanliness. Make sure that the cover fits properly to keep moisture, dirt, and dust from entering. Blow out the cabinet with dry compressed air. Check for corrosion of all metal parts. They may need cleaning and refinishing.

**Exercises (412):**

1. List some of the items to look for when making a visual inspection.

2. What is the maximum air pressure that you can use to clean a motor?

3. What could happen if a motor is lubricated improperly?

4. What would you look for when checking the connections of a motor controller?

## 1-5. Troubleshooting and Repair of Motors and Controls

Troubleshooting is a systematic, methodical determination of malfunctions and defective components and parts by indications, signs, and tests. Pay close attention to the procedures in the text, and you will reduce the time required to locate the trouble and to restore all motorized equipment to its normal operation.

**413. State the problems and probable solutions for problems which may cause troubles in motors and controls.**

Motor failure may be due to a number of causes. Some of the things that may cause motor failures are an overload, low or high voltage, frozen or worn motor bearings, failure of motor windings, and failure of motor controls.

**Troubles in Motors and Controls.** Many things that cause motor failure are not the fault of the motor. Several conditions which may cause motor failure are listed below. These conditions should be checked before disconnecting electrical powerlines or troubleshooting the electrical system.

*a*. Overload.
*b*. Loss of power.
*c*. Driven machine blocked.
*d*. Frozen or worn bearings.
*e*. Bad or improper connections.

*Overload*. If a motor has been operating satisfactorily and suddenly stops, a temporary overload condition may exist. You should allow sufficient time for the overload device to cool before actuating the reset device. If sufficient cooling has occurred, the reset will hold in the locked position and you can follow the normal starting operation. If the motor fails to start, you should employ a systematic procedure for locating the trouble. Check current draw with an ammeter to determine if the motor is overloaded.

*Loss of power*. Use a voltmeter to determine if power is being supplied to the magnetic starter. Likewise, determine if power is being supplied to the motor.

*Bad or improper connections*. Before a motor is removed from the line, you should check all electrical connections. Determine if the control connections are in accordance with the control wiring diagram. When you have checked the control connections, check the terminal lead connections in both the control apparatus and the motor.

Motors with wound rotors are more susceptible to malfunctions due to their construction. Other than insulation checks, which are similar to the stator winding, rotors often have opens caused by overheating. Sometimes these opens can be repaired by using a soldering gun to restore the circuit.

Brushes that have been worn to half their original length must be replaced. Check brushes for broken leads, a chipped or broken face, correct tension, and freedom of movement in holder.

*Driven machine blocked*. Determine if the driven machine is at fault. To do this, disconnect the motor from its load and rotate the rotor shaft of the motor by hand to determine if rotation is free.

*Frozen or worn bearings*. Try operating the motor without the load of the driven machine. Lubrication may be needed and, in some cases, will free the rotor. If the bearings are frozen or stuck, it may be necessary to take the motor apart to free the bearings. If the rotor will turn, look for wobbling, which indicates a bent shaft. Before handling the shaft, however, put on gloves; or use a piece of cloth to insure against injury to hands from burrs or sharp edges that may be in the keyway. Check the rotor shaft for any up-and-down play (movement). Any noticeable movement indicates worn bearings, which may be causing the rotor to be dragging in the stator. This is probable when belt tension is applied. The bearings should be replaced if up-and-down movement is noted. Also check for rotor end play. This is noted by moving the rotor shaft in and out. Some end play is not detrimental; however, it should not exceed 1/64 of an inch. Excessive end play may be removed by adding fiber spacer washers.

Other things to check for are misalignment of endbells, a loose pole piece, or foreign objects in the motor. If the trouble is not mechanical, then analyze the motor circuits.

**Exercises (413):**

1. List five problems which may cause trouble in motors.

2. What instrument should you use to determine if a motor is overloaded?

3. How can you repair opens in rotors caused by overheating?

4. How can you determine if the driven machine is at fault?

5. How can you remove excessive end play in bearings?

**414. Give specific details concerning troubleshooting techniques for motors and controls.**

**Three-Phase Motors and Controls.** All electrical circuits are subject to three common malfunctions. These circuit faults are open, grounded, and shorted circuits.

*Open circuits*. Starting with the source of power, an open circuit may exist at any point between there and the rotor of the motor. It is necessary to isolate the trouble. This must be done on a step-to-step basis. Make the following checks on the equipment shown in figure 1-37. It is very important to remember that you are working with an ohmmeter, and it should not be connected to a live circuit. Figure 1-37 shows a 3$\phi$ motor connected to a 3$\phi$ starter.

With an ohmmeter, check from the source of power to the line terminals of the starter, making sure continuity exists at the starter line terminals L1, L2, and L3. Make sure of a continuous circuit between the start-stop station and the starter. (THE CONDUCTOR CONNECTED TO L1 IS COMMON TO BOTH THE STARTING AND HOLDING CIRCUIT.)

Make sure there is a continuous path for current flow from the switch side of the starter through the holding coil and through the resets, back to L2. This circuit normally is from switch terminal 3, to starter terminal L2. Be sure you have continuity through the heaters. Raise the armature until the contacts are closed and check for continuity between L1 and T1; L2 and T2, and L3 and T3. If there are no opens at this point, power should exist to the motor terminals, T1, T2, and T3 of the starter, when the start button is pushed.

Check for continuity between the starter terminals T1, T2, and T3, and the motor terminals, T1, T2, and T3. If we have continuity to the motor termi[illegible]ill be necessary to check the stator of the motor f[illegible] circuit. This is done in a wye-connected motor, a[illegible]wn in figure 1-38.

Disconnect the motor leads from the power leads. Check for continuity between leads 1 and 4, 2 and 5, and 3 and 6.

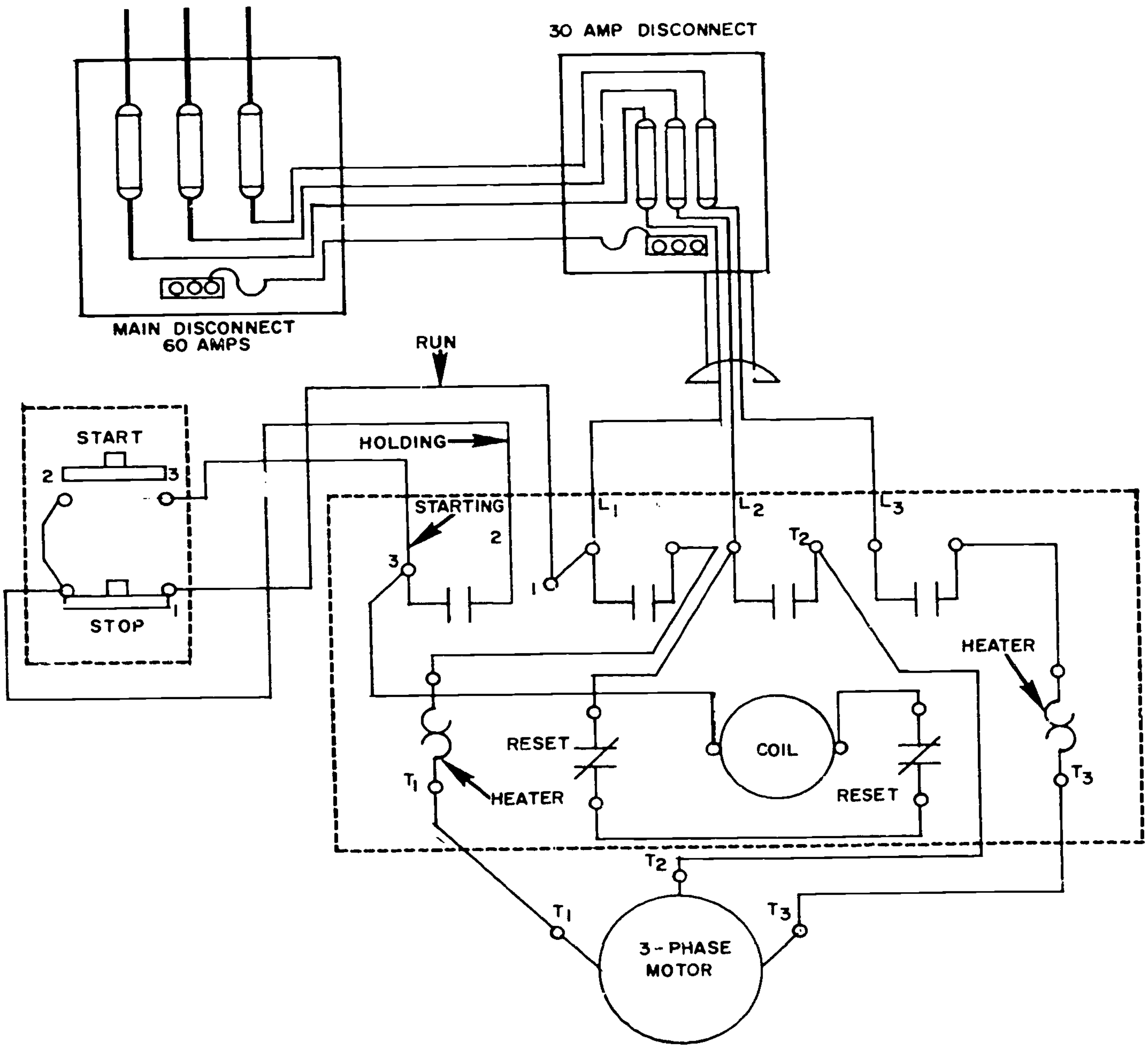



Figure 1–37. Three-phase motor connected to a 3φ starter.

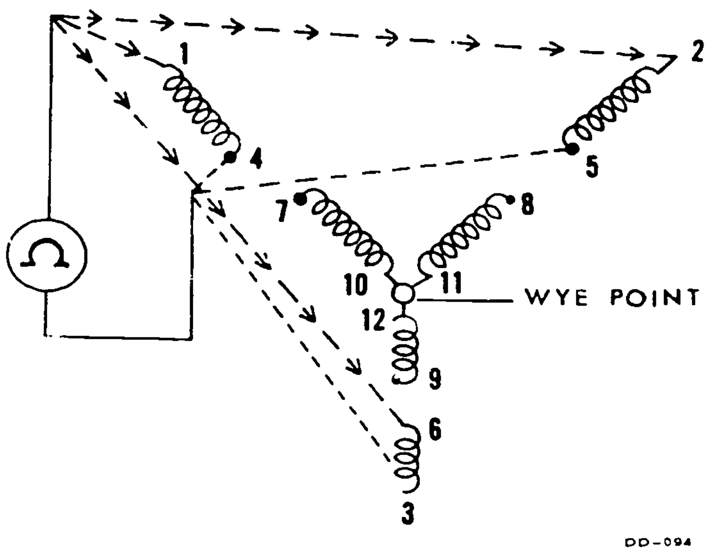



Figure 1–38. Testing the stator of a 3ϕ wye-connected motor for an open circuit.

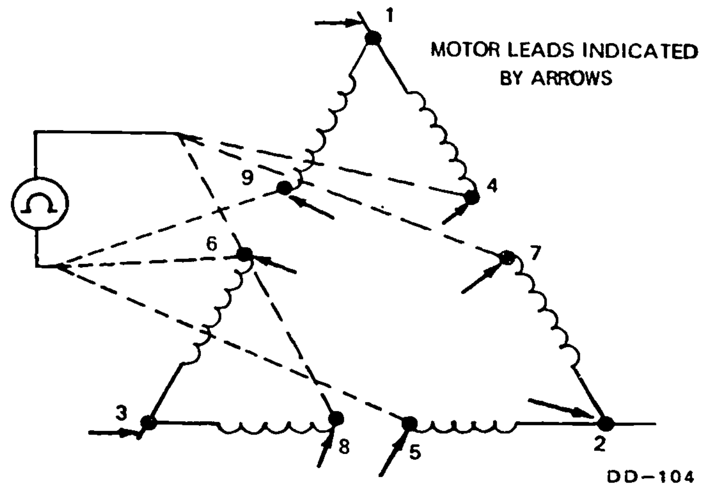



Figure 1–39. Testing a delta-connected motor for an open circuit.

Continuity should exist when testing across the above-mentioned pairs. Since the opposite ends of leads 7, 8, and 9 are connected at a wye point in the wye-connected motor, continuity should exist between leads 7 and 8, 7 and 9, or a combination of 7, 8, and 9.

Checking the stator of a delta-connected, 9-lead motor for an open circuit is accomplished as shown in figure 1-39. Disconnect the motor leads from the power leads. Check for continuity between leads 4 and 9, 6 and 8, and 5 and 7. This will check all the windings in the delta motor, inasmuch as lead 10 is connected internally to lead 2, lead 11 to lead 3, and lead 12 to lead 1.

There is little likelihood that a squirrel-cage rotor will be open. If an open does exist, the motor slows down under load. It also has low starting torque. Signs of heating are usually evident. Fractures in the rotor bars are usually found either at the connection to the end rings or at the point the bars leave the laminations. If the motor has a wound rotor, it may be necessary to check it for an open circuit by using the external growler.

*Grounded circuits*. The same methodical process must be followed in finding a grounded circuit as was employed in finding an open circuit. It is necessary to start with the source of power and work toward the motor. With the main disconnect open, check with an ohmmeter across each power phase to ground. Follow this step all the way to the starter to insure that no grounds exist from the source of power to the starter. Any ground existing in the power supply or any extremity connected to L1, L2, or L3 of the starter will be indicated at any point tested, by the needle movement on the ohmmeter. This is assuming that any disconnects between the source of power and the starter are closed. Disconnection of conductors at certain points will be necessary to isolate the grounded circuit. One at a time, check across each of the conductors, connected to the start-stop station to ground (conduit), to determine if a ground exists to the start-stop station.

Check throughout the starter at points of possible grounds. Also check the control circuit (through the coil) and then your load circuit. In checking T1, T2, and T3 of the starter to ground, remember that any grounds existing in the connected motor will be indicated at these points. Whether the ground exists in the motor or on the conduit can be determined by disconnecting the motor from the starter. If the ground does not exist in the conduit from the starter to the motor, the motor windings must be checked for grounds.

The motor windings are tested for grounds, as shown in figure 1-40. Position one test prod to the motor housing, being certain metal-to-metal contact is established. With the other lead, touch each station lead in succession. If the 1 amp lights, a ground is indicated. All internal motor troubles must be repaired by a motor rewind shop; so if an internal problem is discovered, you should not disassemble the motor but, instead, send it out for repairs.

*Shorted circuits*. Shorted circuits are found by checking across conductors with the power off. If continuity exists across two conductors when the circuit is purposely open, the circuit is shorted. As in checking for opens and grounds, checking for shorted circuits should start with the source of power and be carried through to the motor windings. Figure 1-41 may be used for applying tests for short circuits in the motor windings. With the main disconnect open, start by checking across the fuses (bottom end). Assuming that any disconnects are closed between the source of power and the starter, continuity across any two conductors will indicate that a short circuit exists between the main disconnect and the starter. Disconnection of conductors at certain points will be necessary to isolate the shorted circuit. Press the stop button and check across the conductors on terminal 2 of the starter switch to L1. Pressing the stop button on the start-stop station opens the circuit to the starter. A continuity reading would then indicate a shorted circuit in the holding part of the circuit. (NOTE: This circuit is

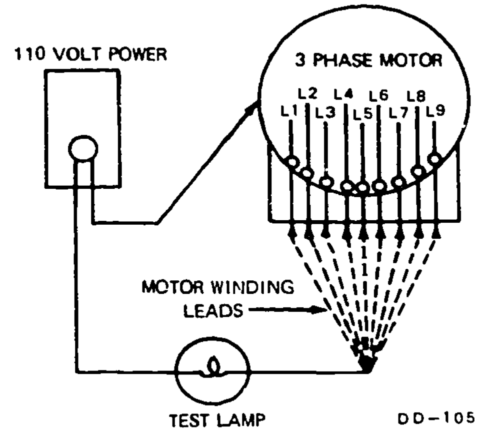



Figure 1–40. Testing motor leads for a grounded winding.

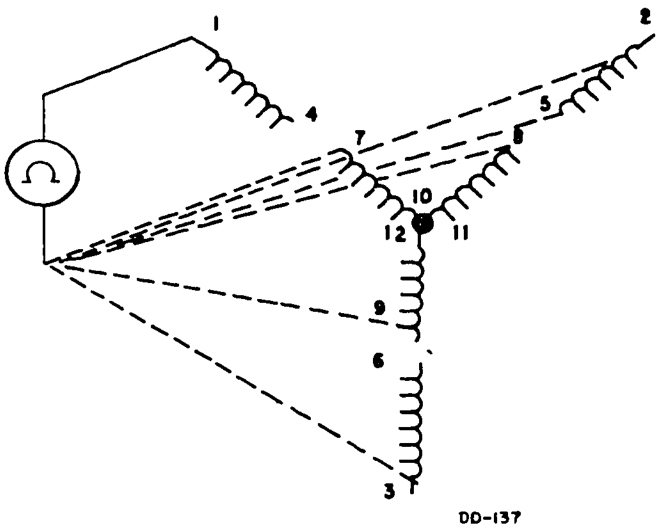



Figure 1–41. Testing a wye-wound stator for a shorted circuit.

normally closed due to the construction feature of the start-stop station.) Continuity across L1 to number 3 in the starter would indicate a shorted circuit in the starting part of the circuit. (NOTE: This circuit is normally open due to the construction feature of the start-stop station.)

When checking across the controller terminals (T1, T2, or T3), it will be necessary to disconnect the motor leads from the source of power; otherwise, there will be a continuity reading, due to reading across the motor windings. After disconnecting the motor leads, continuity should not exist when checking across T1, T2, and T3. Also, check for a short circuit in the conductors in the conduit between the motor and the starter.

Checking a wye-wound motor for a shorted stator winding is accomplished as shown in figure 1-41. Use an ohmmeter to check across the stator leads of the motor for continuity. Continuity should exist between leads 1 and 4, 2 and 5, 3 and 6, and the leads of which the other ends form the wye point. The external leads involved in the wye are leads 7, 8, and 9. Therefore, in testing for a shorted stator, if continuity should exist between any combination of lead numbers other than those which form a winding, a shorted stator is indicated.

Procedures for checking a delta-wound, 12-lead motor for a shorted stator winding are accomplished as shown in figure 1-42.

Continuity should exist across the following leads of a delta-wound stator having 12 external leads: 1 and 4, 2 and 5, 3 and 6, 7 and 10, 8 and 11, and 9 and 12. Therefore, in testing for a shorted stator, if continuity should exist between any combination of numbers other than those shown above, the stator is shorted.

In the 9-lead delta motor, which is most commonly used, three end windings are internally connected. Lead 12 is connected to lead 1, lead 11 to lead 3, and lead 10 to lead 2. Continuity should exist across leads 4 and 9, 6 and 8, and 5 and 7. Therefore, in testing for a shorted stator, if continuity should exist between any combination other than those linked above, providing leads 1, 2, and 3 are not used, the stator is shorted. Leads 1, 2, and 3 are not used because internal leads 12, 10,and 11 are connected to them.

**Single-Phase Motors and Controls.** All electrical circuits in 1$\phi$ motors and controls are subject to the same fault functions as 3$\phi$ motors. Therefore, we will discuss only open circuits.

Starting with the source of power, an open circuit may exist at any point between there and the rotor of the motor. It is necessary to isolate the trouble. This must be accomplished on a step-by-step basis. Make the following checks to the equipment shown in figure 1-43. Check with an ohmmeter from the source of power to the line terminals of the starter, making sure continuity exists at terminals L1 and L2. Make sure of a continuous circuit between the start-stop station and the starter. (THE CONDUCTOR CONNECTED TO L1 IS COMMON TO BOTH THE STARTING AND HOLDING CIRCUIT.)

Make sure there is a continuous path for current flow from the switch side of the starter through the holding coil and through the resets, back to L2. This circuit normally is from switch terminal 3 to starter terminal L2. Be sure you have continuity through the heaters. Raise the armature until the contacts are closed and check for continuity between L1 and T1 and L2 and T2. If there are no opens to

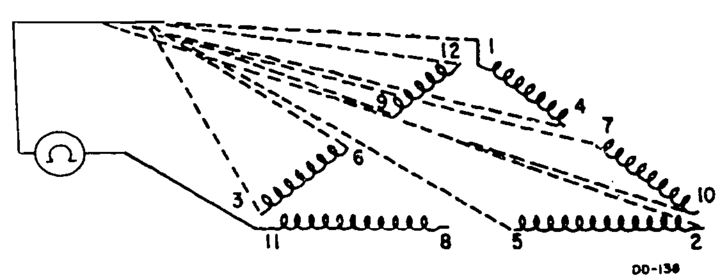



Figure 1–42. Testing a 12-lead, delta-wound stator for a shorted circuit.

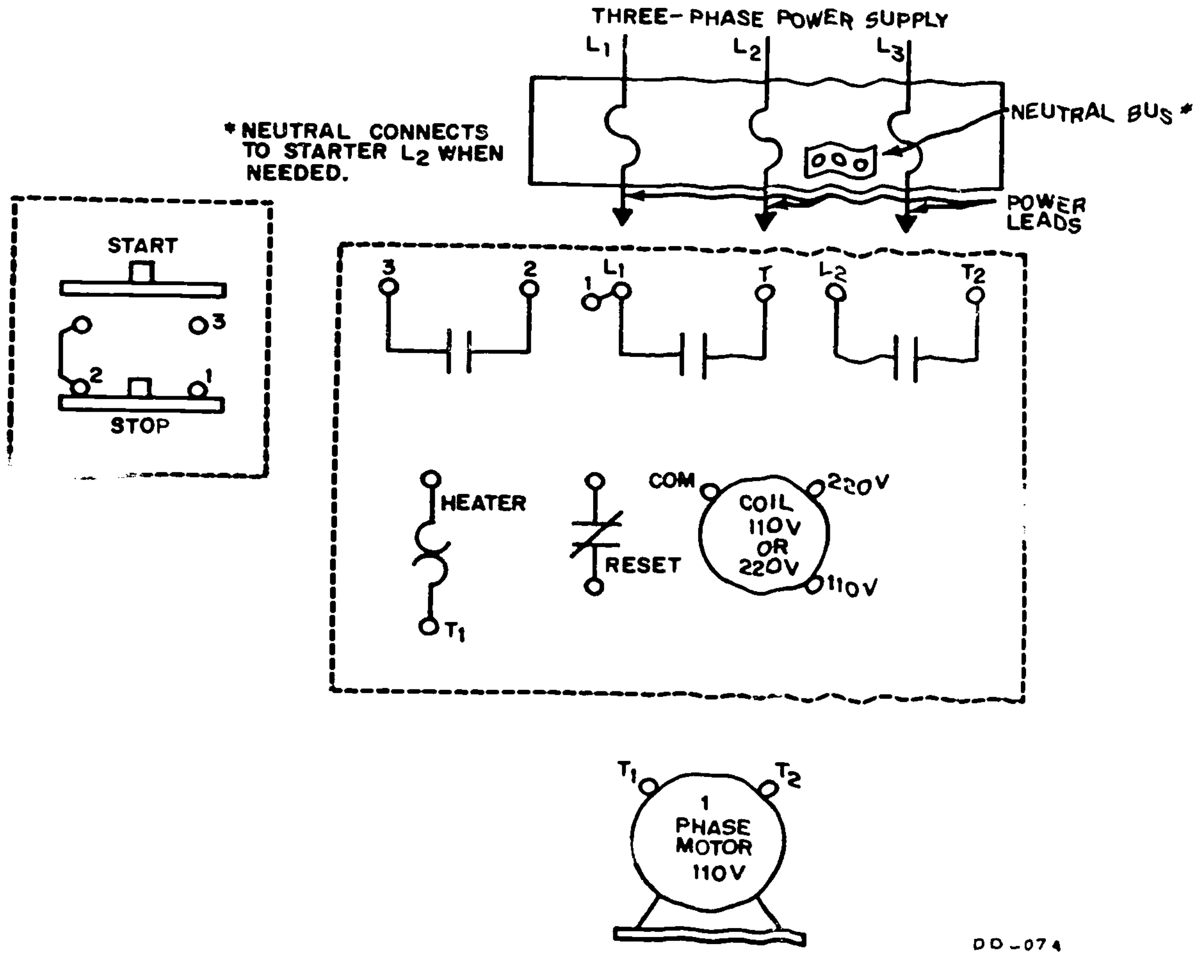



Figure 1–43. Single-phase motor control system.

this point, power should exist to the motor terminals, T1 and T2 of the starter, when the start button is pushed.

Check for continuity between the st. rter terminals, T1 and T2, and the motor terminals, T1 and T2. If we have power to the motor terminals, it will be necessary to check the stator of the motor for an open circuit. Disconnect the motor leads from the power leads. Check for continuity between leads 1 and 2, 3 and 4, and 5 and 8. There is little likelihood that a squirrel-cage rotor will be open. If an open does exist, the motor slows down under load. It also has low starting torque. Signs of overheating are usually evident.

**Exercises (414):**

1. What are three common malfunctions of electrical circuits?

2. Where may an open circuit exi[illegible] a 3$\phi$ motor?

3. Why is it sometimes necessary to disconnect the motor from the starter in a 3$\phi$ motor?

4. When must you check the motor windings for grounds?

5. How can you locate shorted circuits?

6. What would indicate a short circuit between the main disconnect and the start?

7. What would indicate a shorted stator in a wye-wound motor?

8. How does an open circuit affect a 1ϕ motor with a squirrel-cage rotor?

**415. Match the common malfunctions found in motors and controls with their probable causes.**

**Correcting Malfunctions.** All malfunctions in motors and controls may be corrected by an Air Force electrician, except malfunctions in the internal wiring of the motors. nmon malfunctions are:

*a*. Motor will not start.
*b*. Motor runs hot.
*c*. Motor stops running.
*d*. Motor operates with excessive noise.
*e*. Motor runs slowly.

*Motor will not start*. The motor may not start due to a voltage failure. Check the line voltage. Check for blown fuses and broken or loose connections. Replace any bad conductors.

*Motor runs hot*. The motor may be operated under an overload. Check the full-load amperage against the data plate rating. Check the rating of the overload relay against the full-load current. If the rating of the relay is too high, replace it with the proper rated relay.

Check the available voltage to be sure the motor is not operating on under or over voltage. It may be necessary to lighten the load or install a larger motor.

Check for proper motor and power connections. Be sure the motor is properly connected to the available voltage.

Check for proper ventilation. Clean any dirt from around vents or windings.

Check the motor to determine if it has been properly lubricated. If it has not been, oil it according to the manufacturer's instruction.

The motor may overheat due to starting too frequently. Determine if the motor is rated for intermittent duty. If it is not rated for the service required, replace it with one of proper design.

*Motor stops running*. If the motor stops running, allow sufficient time for the motor control to cool. Push the reset into locked position and push in the start button. If the motor starts, maintain close observation until the operator is sure the motor failure was not due to any severe circumstance, the recurrence of which would result in serious damage to the motor. A brief overload or a power failure may have been the cause of the failure. Occasionally, the relay must be replaced because it has been faulty. If the motor cannot be restarted, it may be necessary to recheck all the things previously discussed under the topic "Procedures for Correcting Malfunctions."

*Motor operates with excessive noise*. Excessive noise may result from the motor's not being securely mounted. This condition may be remedied by tightening the mounting bolts and the motor support securely.

Dry motor bearings may cause excessive noise while the motor is in operation. Proper lubrication may stop the excessive noise, providing permanent damage has not been sustained by the bearings. Sufficient damage to the bearings may require that the bearings be replaced. Follow a regular lubricating schedule. Be certain the lubricant is the type suggested by the motor manufacturer.

Excessive noise may be the result of loose motor accessories. You can eliminate this by tightening the oil well cover and the connection box cover. The motor may not be mounted on a solid surface. Replacing the mounting surface may quiet the operation of the motor.

*Motor runs slowly*. When a motor runs slower than it is rated to run, considering slip in induction motors and that there is no overloading of the motor, you must consider other factors. The voltage supply may be deficient, causing a motor to run too slowly. Correct the supply voltage. The voltage must be within 10 percent of the voltage rating for the motor.

The bearings of a motor may be binding. This will cause the motor to run at less than rated speed. The bearings should be replaced if needed. Cleaning and relubrication may correct the trouble.

The driven machine may cause a motor to run slowly. When it is suspected that the driven machine is at fault, the motor should be disconnected from its load and tested independently of the machine.

Occasionally a rotor may be open. This will result in the motor slowing down under load. The rotor must be repaired or replaced.

When troubleshooting 1ϕ motors, you should check for such items as bad centrifugal switches, bad brushes, and bad capacitors.

If a split-phase motor hums but will not start, the trouble will probably be in the centrifugal switch or bad start windings. This same problem with a capacitor start motor might mean the motor has a bad capacitor. All other checks are the same for both 1ϕ and 3ϕ motors.

For additional information on use, care, and maintenance of electric motors, refer to Technical Manual TO 34Y 19–1–1.

**Exercises (415):**

1. Match the malfunctions in column B with their causes in column A.

*Column A*

______(1) Improper ventilation.
______(2) Blown fuses.
______(3) Power failure.
______(4) Faulty relay.
______(5) Open rotor.
______(6) Deficient voltage supply.
______(7) Dry motor bearings.
______(8) Too frequent starting.
______(9) Insecure mounting.
______(10) Bad conductors.
______(11) Faulty driven machine.
______(12) Voltage failure.

*Column B*

a. Motor will not start.
b. Motor runs hot.
c. Motor stops running.
d. Motor operates with excessive noise.
e. Motor runs slowly.

# Systems in Harzardous Locations

DURING YOUR career as an electrician, you will work in areas where hazardous conditions are present. A hazardous location is one in which you find explosive vapors, dust, and fibers. The installation of ordinary wiring in these areas creates conditions which could produce an explosion.

## 2-1. Types of Hazardous Locations

[illegible] must give special consideration to the wiring in hazardous locations, because the safety of personnel is involved. Switches, outlets, and lighting fixtures must be totally enclosed. Hazardous areas, such as crude oil refineries, flour mills, and gasoline service stations, must be wired with specially constructed boxes and fittings.

**416. Distinguish among the types of hazardous locations.**

**Classes.** Hazardous locations are divided into three classes. These classes are determined by the uses of the location. Let's see what each of these classes means:

*Class I.* These locations are those places in which flammable gases, vapors, or liquids are, or may be, present in the air in large enough quantities to produce explosive mixtures. These locations include hospital operating rooms, fuel-handling areas, and similar surroundings.

*Class II.* These locations are those places in which combustible or explosive dust is, or may be, present in the air in sufficient quantities to produce an ignitable or explosive mixture. Some of these locations are flour mills, grain elevators, and coal pulverizing plants.

*Class III.* These locations exist where there is the presence of easily ignitable fibers or flyings. The term "flyings" is used to designate waste such as sawdust, wood chips, and other such combustible materials. These materials are likely to be suspended in the air in sufficient quantities to produce a combustible mixture. Locations include such places as textile mills and woodworking shops.

**Divisions** [illegible] ese classes is divided into two divisions [illegible] o determine just how the wi[illegible]

*Division 1.* Denotes that the particular danger is eminent at any or all times during the normal course of operation.

*Division 2.* Denotes that the danger is not believed present under normal conditions, but is likely to arise from a reasonably foreseeable accidental occurrence.

For example, a building which houses a machine for compressing acetylene gas will fall within Class I, Division 1. If high-pressure mains from this machine pass into another building where shut-off valves and pressure-recording instruments are inserted in these lines, this adjacent building comes under the heading Class I, Division 2.

**Exercises (416):**

1. What factor determines the class of a hazardous location?

2. What does a Division 1 classification of a building denote?

3. What does a Division 2 classification of a building denote?

4. Give examples of Class I hazardous areas.

5. Name three Class II hazardous locations.

6. What hazardous location exists when ignitable fibers are present?

7. Which class ex[illegible] when large quantities of flammable ga[illegible]s are pre[illegible]n the air?

## 2-2. Material Used for Hazardous Locations

General purpose electrical equipment is not designed for hazardous locations. The materials used in these hazardous locations are of a special design and are usually made of cast iron which allows them to withstand hazardous areas.

In this unit we will discuss the electrical material used when installing electrical systems in hazardous locations.

## 417. Explain pertinent facts about materials used for hazardous areas.

**Hazardous Area Equipment.** The electrical equipment used for hazardous areas differs from standard material used in general electrical construction. Standard electrical equipment is not explosion-proof, dust-proof, or spark-proof unless so stated by the manufacturer. The manufacturer will usually identify various types of equipment for hazardous locations. In most cases, they will specify the classes the equipment can be used in or will state whether the equipment is explosion-proof dust or spark-proof. Remember, equipment designed for one class is not always recommended for another hazardous class.

*Explosion-proof equipment.* Electrical equipment used in Class I locations must be explosion-proof. Explosion-proof means that all fittings and equipment must be able to withstand an explosion that may occur within. For example, inclosures containing devices must be strong and rigid enough to withstand an internal explosion without cracking or breaking. This prevents ignition of explosive vapors surrounding the explosion-proof inclosure.

Figure 2-1 shows one type of explosion-proof junction box at the top and two different types of explosion-proof lighting fixtures at the bottom.

Figure 2-2 shows an explosion-proof conduit union, and figure 2-3 shows another type of explosion-proof junction box.

*Dust Ignition-Proof equipment.* Equipment designed to be dust ignition proof is used in Class II hazardous areas. Electrical equipment of this type is constructed like explosion-proof equipment and serves the same purpose. It is inclosed in such a way that it excludes ignitable amounts of dust, which could affect the operation of equipment, from entering the enclosure. The system is also designed to prevent arcs and sparks from leaving the inclosure and into the hazardous area. Figure 2-4 shows a dust-proof receptacle, and figure 2-5 illustrates a dust ignition-proof fluorescent fixture.

*Spark-proof equipment.* Spark-proof equipment is used in Class III hazardous locations. The inclosure must be constructed without holes so that sparks or burning material cannot escape and ignite any combustible material. This can be done by using tight metal inclosures which will also minimize the entrance of fibers and flyings into the electrical inclosures.

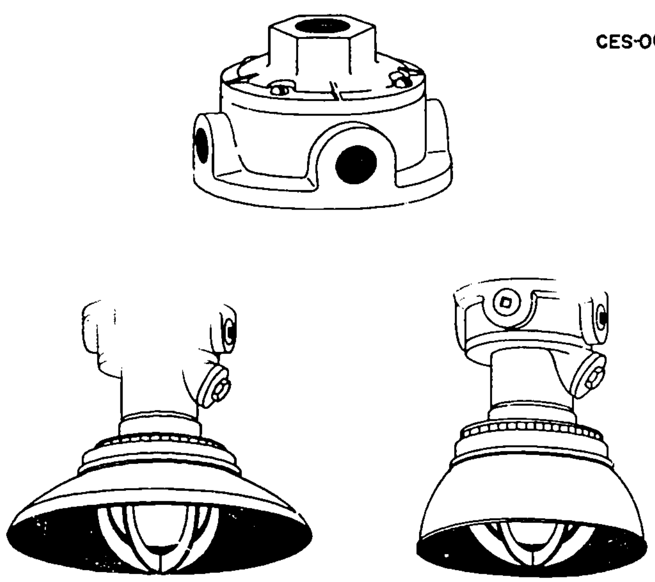

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Figure 2-1. Explosion-proof fixtures.

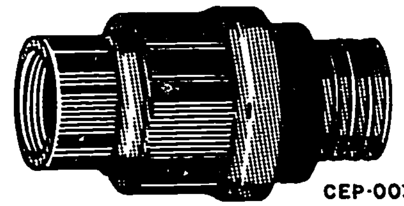
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Figure 2-2. Explosion-proof conduit unions.

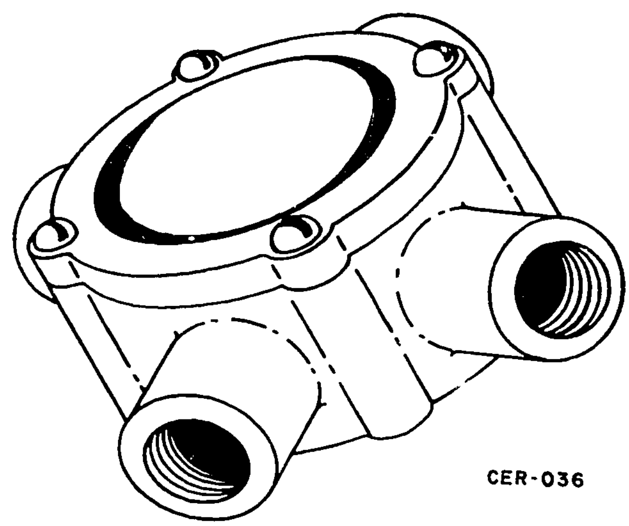
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Figure 2-3. Explosion-proof conduit junction box.

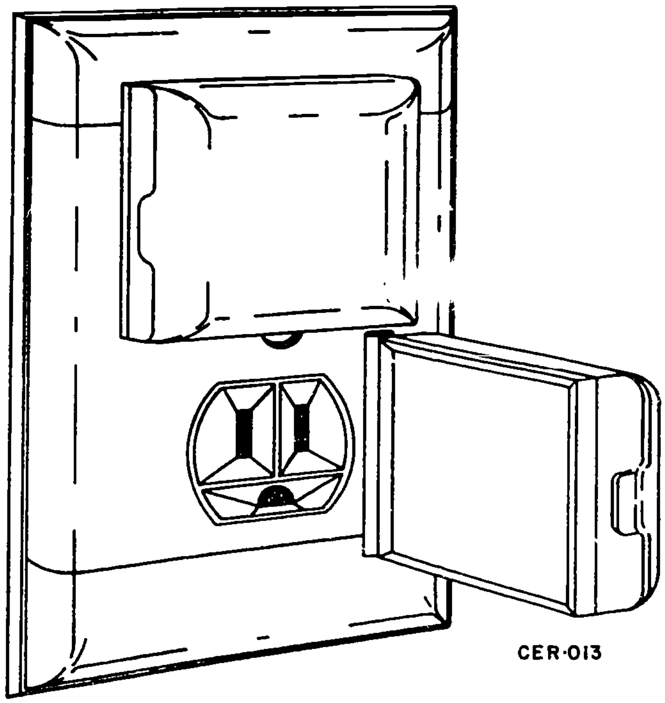


Figure 2–4. A dustproof receptacle.

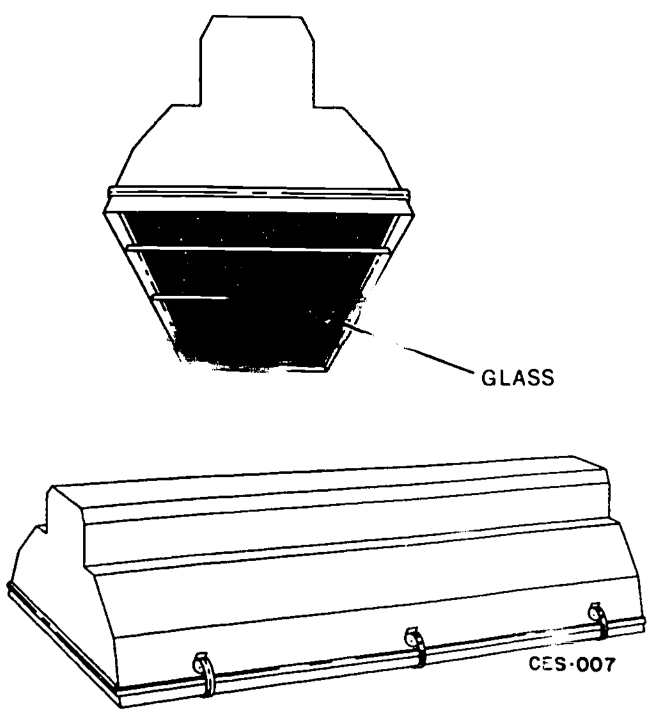


Figure 2–5. Dust-ignition proof fluorescent fixture.

**Exercises (417):**

1. How can hazardous area electrical equipment be distinguished from standard electrical equipment?

2. Is equipment designed for Class I locations always recommended for other hazardous areas?

3. What hazardous class requires the use of explosion-proof equipment?

4. Which class of hazardous equipment is designed to exclude ignitable amounts of dust from the inclosures?

5. Equipment used in Class III hazardous areas must be ________.

## 2-3. Installation of Wiring in Hazardous Locations

At one time or another, you will be required to install or replace electrical wiring or equipment in a hazardous location, which could endanger lives and equipment if not installed correctly. For this reason, you should always have respect for the conditions in hazardous areas. In this section, we will cover some of the basic requirements for hazardous locations.

**418. Explain specific requirements concerning the installation of hazardous location wiring**

**Installation Requirements.** Whenever possible, you should install the majority of the wiring system outside the hazardous area. This will save labor costs and reduce the expense of equipment designed for hazardous locations. In most cases, the wiring outside the hazardous area can be installed using standard wiring devices. For example: the paint spray booth at the base auto hobby shop has explosion-proof lighting fixtures inside the booth. The control device used to operate these lights could be located outside the hazardous area, therefore reducing installation cost and minimizing equipment in hazardous locations. The wiring that is located in the hazardous area must meet rigid requirements.

*Class I installation*. In general, Class I locations require the use of explosion-proof equipment. Threaded rigid metal conduit, IMC (intermediate metal conduit) and type MI cable (mineral-insulated cable) are the only wiring methods suitable for use in Class I locations. The conduit must be

threaded with 3/4-inch tape per foot. Conduit must be made up wrench-tight to minimize sparking when fault current flows through the conduit system.

All fittings such as outlet boxes, junction boxes, and inclosures should have threaded hubs to receive the conduit and must be explosion-proof. The hubs of these fittings must engage at least five full threads of conduit. The covers for junction boxes are either screwed on with a sufficient number of threads engaged to make them explosion-proof or have a machined fit with a tolerance of 0.002 inch and at least 3/8 inch wide, either of which experience has shown will confine the explosion.

When a number of fittings or inclosures are installed using conduit, explosive gases or other materials can pass from one fitting or inclosure to another, through the conduit. The conduit, itself, can also contain a substantial amount of such explosive material. To minimize the quantity of explosive material that can accumulate in any one place, seals, commonly called seal-offs, are installed. The seal is installed in the run of conduit; and after the wires are pulled into place, it is filled with a sealing compound that effectively prevents explosive materials from passing from one portion of the electrical installation to another, throughout the conduit. Most seals will be installed within 18 inches of each piece of equipment that produces arcs or sparks, such as switches or circuit breaker panels. Figure 2-6 shows a seal-off.

Figure 2-7 illustrates a typical Class I installation. All equipment installed in this area shall be explosion-proof. Notice that a seal is installed where the feeder enters the hazardous area. All conduit is rigid metal and all fittings are threaded. Probably the most important item to consider when installing electrical equipment in hazardous locations is to use the right equipment, no matter what you are installing—light fixtures, motors or controls, or circuit breakers and panelboards.

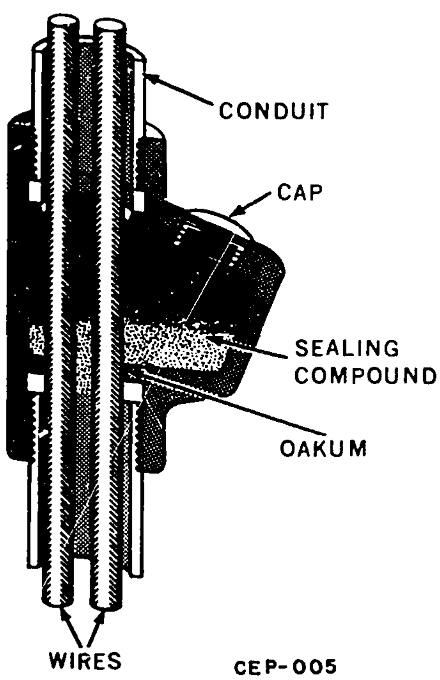


Figure 2-6. A seal-off.

In locations where explosive gases or vapors exist, bare lamps or non-explosion-proof inclosed fixtures constitute hazards. Bare lamps may be broken or loosened in their sockets, thereby causing explosions. For this reason, such lamps must be in an inclosure designed for the area it is installed in.

The exposed noncurrent-carrying metal parts of equipment, such as the frames or metal exteriors of motors, fixed or portable lamps or other utilization equipment, lighting fixtures, cabinets, cases, and conduit, must be grounded.

The locknut-bushing and double-locknut metal contacts must not be depended upon for bonding purposes for conduit or raceway between Class 1 locations and the service equipment. Bonding jumpers with proper fittings or other approved means shall be used.

*Class II installation*. Electrical equipment in Class II locations must be dust ignition-proof. The wiring method is essentially the same for Class II as it is for Class I. All boxes and fittings must be threaded and have dust-tight covers. The inclosures must prevent arcs, sparks, and heat generated within the equipment from igniting the dust in the air around the equipment.

*Class III installation*. The wiring and equipment used in Class III areas must have tight metal inclosures to minimize the entrance of fibers and to prevent the escape of sparks. The wiring method shall be generally the same as Class I and II threaded rigid metal conduit, IMC, or type MI cable.

**Exercises (418):**

1. What type of conduit is required in a Class I installation?

2. Why must conduit in hazardous areas be wrench-tight?

3. Where conduit enters hubs on boxes in Class I locations, at least _____ full threads must be engaged.

4. What fittings are installed to prevent the transfer of gases from one location to another in a hazardous area?

5. What is the installation requirement for electrical equipment used in Class II hazardous locations?

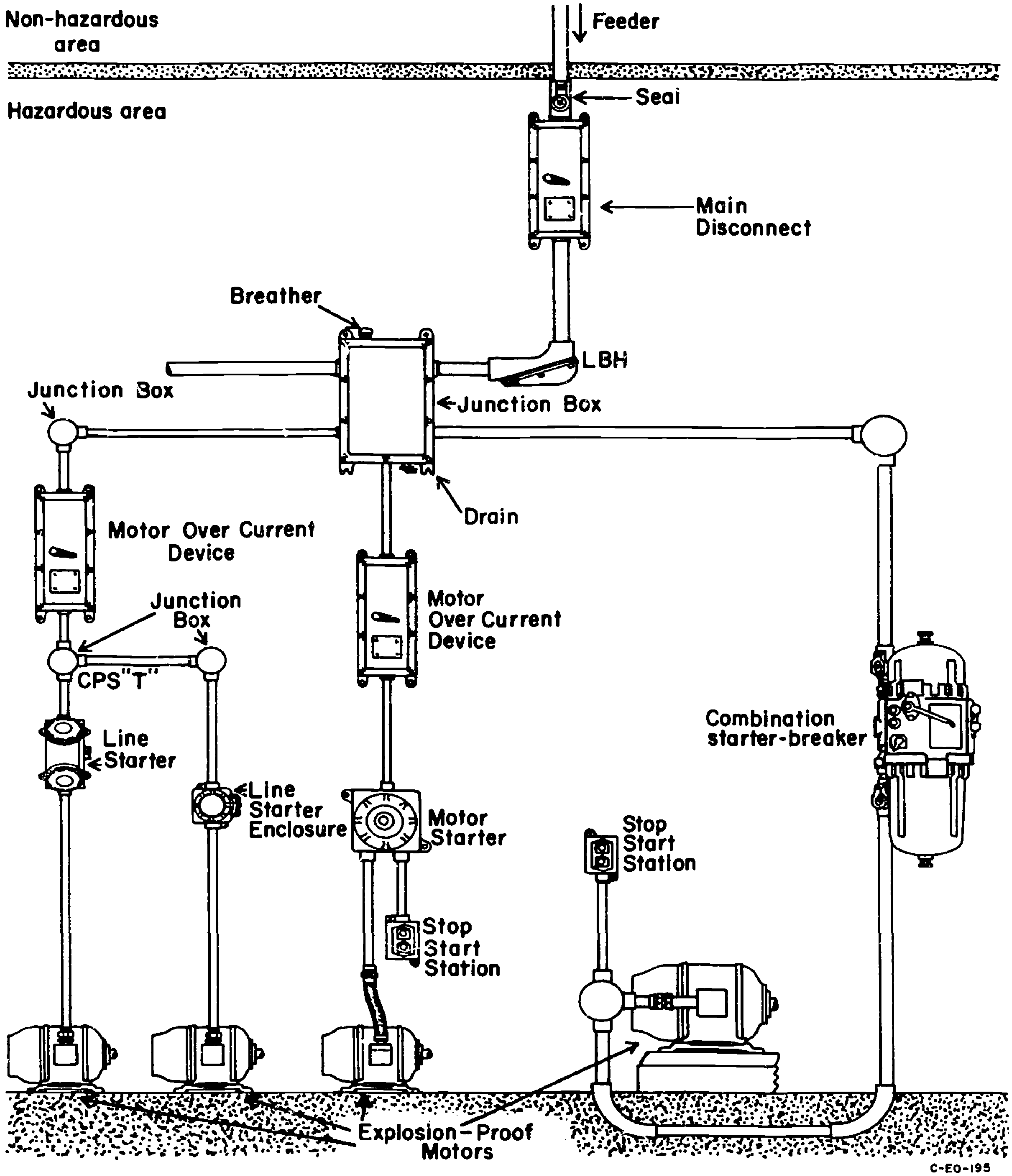


Figure 2–7. Class I installation.

6. Why should the majority of a wiring system be located outside of a hazardous area?

## 2-4. Maintenance of Systems in Hazardous Locations

Once a system has been installed in a hazardous location, maintenance must be performed periodically to insure that safety and operation features are preserved. A good maintenance program will include inspection, troubleshooting, and repair or replacement of faulty parts.

**419. Interpret appropriate actions in the maintenance of hazardous location electrical systems.**

**Inspection and Maintenance Procedures.** Maintenance should be a satisfying part of any interior electrician's daily tasks. But at times, when all fuses seem to blow at once, maintenance will be a throbbing headache. Nevertheless, preventive maintenance will usually occupy most of an electrician's time. Why? Because once equipment has been installed, it is expected to remain in service for some time. It is the responsibility of the preventive maintenance program to see to it that the equipment does have a long life, and this program will be part of your responsibility as an electrician.

The selection, location, and actual installation of the original equipment primarily determines your maintenance program. In a well-planned program, your maintenance is merely a system of routines designed to keep the equipment in satisfactory operating condition through periodic inspections, cleaning, tightening, adjusting, and lubricating. And if you follow that order of tasks, you should be able to prevent operational breakdowns.

In hazardous locations, electrical systems must be installed in such a way as to insure safe performance and/or conditions of proper use and maintenance. Therefore, it is assumed that users will exercise special care in installation and maintenance.

You will find it necessary to organize a step-by-step operation in order to have a methodical, effective, preventive maintenance program. The program usually includes inspections of insulation, conduit fittings and connections, and all electrical operating devices.

*Electrical circuits.* Electrical equipment should be serviced or disassembled only after first deenergizing the electrical supply circuits. This also applies when lighting fixtures or units are partially disassembled for relamping. All electrical inclosures should be tightly reassembled before the supply circuits are reenergized.

*Cover attachment screws.* All cover screws and bolts intended to hold explosion-proof joints firmly together must always be tight while circuits are alive. Leaving one screw or bolt loose may render the equipment unsafe. Take care to use only bolts or screws provided by the equipment manufacturer, since the substitution of other types of material may weaken the assembly and render it unsafe.

*Assembly or disassembly of inclosures.* Do not allow hammers or prying tools to damage the flat ground-joint surfaces. Do not handle covers roughly or place them on surfaces that might damage or scratch the flat ground-joint surfaces. Protect all surfaces that form a part of the flame path from mechanical injury. In storing equipment, always make sure that covers are assembled to their mating bodies.

*Cleaning and lubrication.* Do not allow particles or foreign material to accumulate on flat ground-face joints, since these materials tend to prevent a close fit and may permit dangerous arcs, sparks, or flames to penetrate them, causing fire. When assembling, remove all old grease, dirt, paint, or other foreign material from the surfaces, using a brush and some type of solvent material. Apply a film of light oil or lubricant of a type recommended by the original equipment manufacturer to both body and cover joint. Any lubricated joints exposed for long periods of time may attract small particles of dirt or other foreign material. To avoid this, body and cover joints should be reassembled immediately. Tighten threaded joints sufficiently to prevent accidental loosening due to vibration, but don't force them. If the threads are kept clean and lubricated, safe operation can be assured with a minimum of maintenance.

*Shaft and bearing surfaces.* Because a rotating shaft must turn freely, the clearance between shaft and bearing are carefully established within close tolerances by the equipment manufacturer. Maintain this clearance to prevent flames or sparks from escaping to the outside hazardous atmosphere. Always follow the manufacturer's recommendations with respect to lubrication and other servicing.

*Corrosive locations.* Lubricate threaded covers, flat joints, surfaces, rotating shafts, bearings, and operating shafts well. If corrosion products have accumulated on explosion-proof joints or surfaces and cannot readily be removed with solvents, discard and replace the parts. Never use an abrasive material or a file to remove the corrosion products from threaded or flat-joint surfaces. In extremely corrosive locations, periodically inspect equipment to guard against unusual deterioration and possible porosity, since this may weaken the inclosure structurally.

*Portable equipment.* Frequently examine and replace extra hard usage rubber-covered flexible cord used with this equipment at the first indication of mechanical damage or deterioration. Maintain terminal connections to the cord. In general, where portable equipment is necessary, avoid rough handling and inspect the assembly frequently.

*Over-all safety.* Safety in hazardous locations may be endangered if additional openings or other alterations are made in assemblies specifically designed for use in these locations. In painting the exterior of housings for hazardous locations, take care not to obscure the nameplate, which may contain cautionary or other information of importance to maintenance personnel.

*Plug-in replacement units.* One technique that speeds and eases the work of the maintenance department is the use of plug-in type electrical equipment. Such equipment allows the substitution of a replacement unit while the original unit is being repaired outside the hazardous area.

*Insulation.* The insulation materials on conductors in panels shield or protect the conductors from accidental

contact with other conducting substances. The materials are formed on the conductor during manufacture, or you may install them during the system's installation. You must remember that it is important to maintain these protective coatings or shields on the conductors. Your preventive maintenance should, therefore, include periodic insulation resistance tests and checks to expose potential trouble locations in panels. You may find that the wire insulation has become frayed or that protective devices have been damaged. These wire areas and locations should either be taped, repaired, replaced, or possibly relocated to prevent future damage.

You must also include conductor shielding, which is installed on conductors during installation, in your maintenance program. Replace such shielding as protective sleeving, anti-short bushings, and damage protection when it becomes dislodged or damaged. Conductor or conductor inclosure supports should also be periodically inspected to insure a trouble-free operating system. Replace them in case of trouble.

*Fittings and connections*. To avoid the possibility of short circuits in panels, you must periodically spot check the electrical conduit connections and fittings. These fittings include such items as conduit couplings, connectors, and box entry devices. You must check these fittings for looseness or separation; they should be tightened or the conduit reclamped or resupported when necessary. The only exception is a seal off, because once installed, the sealing compound should not be disturbed.

The conductor connections made to electrical devices or other conductors must also be included in your periodic maintenance checks to determine the condition of splices, wiretaps, and terminal connections. Loose, partly contacting or partly broken connections at the screw terminals or splices of an electrical device can cause short circuits or arcing, especially if the free wire contacts other metallic components which are grounded. Excessive heat is actually the problem, since the heat created by the loose connections causes an increase in amperage, which in turn generates more heat.

Moreover, the increased resistance resulting from a loose or poor connection increases the voltage drop in the circuit, causing inefficient operation of the power load on the system. If this increased resistance in the wire or terminal connections is high enough, the heat resulting from the resistance in an electrical connection may reach a temperature which will ignite the insulating and surrounding materials and provide the basis for a fire. Consequently, on equipment or in circuits, you must tighten or repair all electrical connections which you find loose. One sign of a poor connection is corrosion. Be sure that if you find such a situation, you clean and retighten the connection and correct the cause.

*Devices*. The importance of periodically inspecting all electrical operating devices for defects cannot be over emphasized. A simple observation on your part can detect most serious difficulties within an electrical system. Your periodic inspection, checks, and tests of equipment and devices must include the normal operation under a specified rated load. Repair or replace any device which fails these tests or which is broken or loosely supported in its mountings. If breakage should occur repeatedly in specific locations, you should either replace the electrical equipment or the device with items able to withstand the intended use or relocate the equipment or device to a more applicable and suitable place.

**Exercises (409):**

Indicate whether each of the following statements is true or false by placing a T or F in each blank. Correct false statements.

_____ 1. Before servicing or disassembling equipment in a hazardous location, the supply circuit must be deenergized.

_____ 2. Leaving a screw or bolt out of an explosion-proof box cover could render the equipment unsafe.

_____ 3. When disassembling or assembling hazardous equipment, care should be exercised not to damage surfaces.

_____ 4. When storing hazardous equipment, covers and their mating bodies should be stored separately.

_____ 5. Particles of foreign material accumulating on surface joints of inclosure are necessary to make a close fit.

_____ 6. Always use abrasive material to remove corrosion products from threaded or flat-joint surfaces.

_____ 7. Flexible cords used with portable equipment in hazardous areas must be replaced if mechanical damage or deterioration is found.

_____ 8. When painting the exterior surfaces of equipment in hazardous locations, avoid painting the nameplate.

_____ 9. If, during a preventive maintenance inspection, you find frayed or damaged insulation on conductors, these wires must be taped, repaired or replaced.

_____ 10. Loose connections found on an inspection must be corrected to prevent excessive heat.

_____ 11. A good indication of a poor connection is corrosion.

_____ 12. If a device fails to operate when an inspection and maintenance check is being performed, it should be repaired or replaced.

**420. Identify proper methods of performing specific troubleshooting and repair and replacement procedures in hazardous locations.**

**Troubleshooting Procedures.** In order to keep electrical equipment operating at peak efficiency, both the circuits and the equipment must be kept in top operating condition. Sometimes trouble will develop and must be repaired; however, before troubles can be corrected, they must be located. As with maintenance, it is of utmost importance that all electrical equipment be deenergized before disassembling and troubleshooting an electrical circuit.

Basic troubleshooting techniques and types of electrical troubles will not be covered in this section. Refer to Volume 2, Chapter 9, of this CDC for information concerning electrical troubles. This section will be concerned with specific requirements and procedures required when troubleshooting in hazardous areas.

*Spark-hazard precautions.* To avoid spark hazards, you must make every effort to eliminate hazardous conditions. When you must do work where you cannot eliminate spark hazards, you must make a safety engineering analysis of the work area and the operation. If the analysis shows an unacceptable degree of risk, develop and use precautions, procedures, and tools that will insure a safe operation under the circumstances.

You must take more than ordinary care when troubleshooting equipment in hazardous locations. All work that is done in a hazardous location must be done by qualified persons authorized to do such work.

*Non-spark-producing tools.* In some instances, it has been required in the past to use non-spark-producing tools in hazardous locations. After some research in this area, Air Force directives have determined that no safety advantage is gained by using nonferrous tools. This means that when working in a hazardous area, no special hand tools are required.

All flashlights and lanterns powered by low voltage dry cell batteries must be approved for use in the area in which they are used. For example, if you were working in a Class II area, your flashlight must be rated for a Class II hazardous location. A flashlight approved for a Class I hazardous location is considered satisfactory for both Class I and Class II hazardous locations.

Use type SO flexible hand service cord for any electrical tools or extension cords. Use three-wire cords for equipment in Class I and Class II locations, so that all external parts are effectively grounded. All cords will also have a three prong attachment plug.

*Test equipment.* Use the weakest possible power source for electrical or electronic test equipment. If feasible, use battery-powered equipment instead of that with a 110-volt source. In any event, the test power source should not be capable of initiating the hazardous substance in that area. Where greater power must be used, provide positive safeguards to prevent delivery of enough power to ignite any hazardous substance.

Do not place test equipment in hazardous locations unless necessary; even then it must be suitable for safe operation in that environment. Give special attention to the ventilation requirements of equipment containing vacuum tubes and the possibility of malfunction of equipment using resistors and other devices for limiting testing power. Unless the test equipment is incapable of igniting the item being tested, provide operational shields where needed to protect personnel from injury.

**Repairing and Replacing Procedures.** Before it is placed into routine operation, all newly repaired process equipment for use in a hazardous location or operation must be examined and tested to assure that it is in safe working condition. This must be done by a designated person. If the machinery or equipment does not appear to work properly, discontinue operation if the immediate stoppage does not create a new hazard.

Before repairs are allowed on any equipment that has been exposed to a hazardous substance, clean the equipment and tag it. The operating supervisor must sign the tag, certifying that all substances have been removed. If it is impossible to clean some part of the equipment, note this on the tag, together with clear instructions to electrical personnel on how to handle it safely.

Do not undertake major repairs or changes in a hazardous location during regular operations without removing the hazardous material. Obtain the consent of the immediate supervisor in charge of the area.

Before beginning repairs in a hazardous location, inspect the area for the presence of any hazardous substance. Remove all such material from equipment, crevices beneath floors, within walls and pipes, and under fittings where these substances may be ignited. The area should be wet or be washed down thoroughly.

When electrical personnel enter buildings in which conductive shoes are required, all electrical equipment must be deenergized. Electricians must normally wear nonconductive shoes to prevent any electrical hazards from developing.

**Exercises (420):**

Indicate whether each of the following statements is true or false by placing T or F in each blank. Correct false statements.

_____ 1. To avoid spark hazards, you must make every effort to eliminate hazardous conditions.

_____ 2. All electrical work done in hazardous locations must be performed by qualified persons only.

_____ 3. A good lantern to use in a hazardous location is one powered by 115 VAC.

_____ 4. All test equipment used for troubleshooting must be located in the hazardous area.

_____ 5. Repairs of hazardous location wiring should always be done after removing the hazardous material.

# Special Equipment

THIS CHAPTER deals with the operation and function of transformers, regulators, battery banks, chargers, emergency lights and appliances. These devices are used extensively in electrical systems in the Air Force. As an electrician, you should have a background concerning these components. This will help you understand the base installed electrical systems.

## 3-1. Transformers

When you studied AC circuits in Volume 2 of this CDC, you learned that AC as a source of power has certain advantages over DC. The most important advantage of AC is that the voltage level can be increased or decreased by means of a transformer. Although transformer theory and application were also covered in Volume 2 of this CDC, we are going to review some of the material here to refresh your memory.

**421. Identify structural and operational details of transformers.**

**Transformers.** A transformer is a device having no moving parts which transfers energy from one circuit to another by electromagnetic induction. The energy is transferred always without a change in frequency but usually with changes in voltage and current. A step-up transformer receives electrical energy at one voltage and delivers it at a higher voltage. Conversely, a step-down transformer receives energy at one voltage and delivers it at a lower voltage. You are normally working with step-down transformers. You need to give little care and maintenance to the transformers because of their simple, rugged, and durable construction. The efficiency of transformers is responsible for the extensive use of AC. The conventional constant-potential transformer is designed to operate with the primary connected across a constant potential source. The secondary voltage is substantially constant from no load to full load. Let us briefly review the construction of transformers.

*Transformer construction*. The typical transformer has two windings that are electrically insulated from each other. These windings are wound on a common magnetic core made of laminated sheet steel. The principal parts are: (1) the core, which provides a circuit of low reluctance for the magnetic flux; (2) the primary winding, which receives the energy from the AC source; (3) the secondary winding, which receives the energy by mutual induction from the primary and delivers it to the load; and (4) the case that protects the transformer from moisture and physical damage and also helps to cool the transformer unit.

The most commonly used forms of transformer construction are the core and the shell types. The cores are built of thin stampings of silicon steel. In the core type of transformer, the copper windings surround the laminated steel core. In the shell type of transformer, the core surrounds the copper windings. Control and small power transformers are generally of the core type, while some of the largest power transformers are of the shell type.

Control and signal transformers are normally self-air-cooled. They may be of the open type with no protective casing over the windings or of the inclosed type with a metal casing over the windings.

Distribution and large power transformers are normally cooled by placing the complete core and coil assembly in a steel tank and immersing this in a special mineral oil to insulate and cool the unit. Transformers are built in both single-phase and polyphase units. A three-phase (polyphase) transformer consists of a separate insulated winding to each of the different phases.

*Principles of operation*. The operation of a transformer is based on the principle that electrical energy can be transferred efficiently by mutual induction from one winding to another. When the primary winding is energized from an AC source, an alternating magnetic flux is established in the transformer core. This flux links the windings of the primary and secondary, thereby inducing voltage. Because the same flux cuts both windings, the same voltage is induced in each turn of both windings. Therefore, the total inducted voltage in each winding is proportional to the number of turns in that winding. This is shown in figure 3-1.

The voltage induced in the secondary will depend on the number of turns in the secondary and the number of turns in the primary. For example, if there are 1000 turns in the secondary and 100 turns in the primary, the voltage induced in the secondary will be 10 times the voltage applied to the primary. If there are more turns in the secondary than there are in the primary, the transformer is called a step-up transformer. If, on the other hand, the secondary has 10 turns and the primary has 100 turns, the voltage induced in the secondary will be one-tenth of the voltage applied to the primary. Since there are fewer turns in the secondary than there are in the primary, the transformer is called a step-down transformer.

*Transformer losses*. Not all electrical energy from the primary coil is transferred to the secondary coil. A transformer has some losses. The actual efficiency is less than 100 percent but usually more than 90 percent. There are two types of transformer losses: copper losses and core losses.

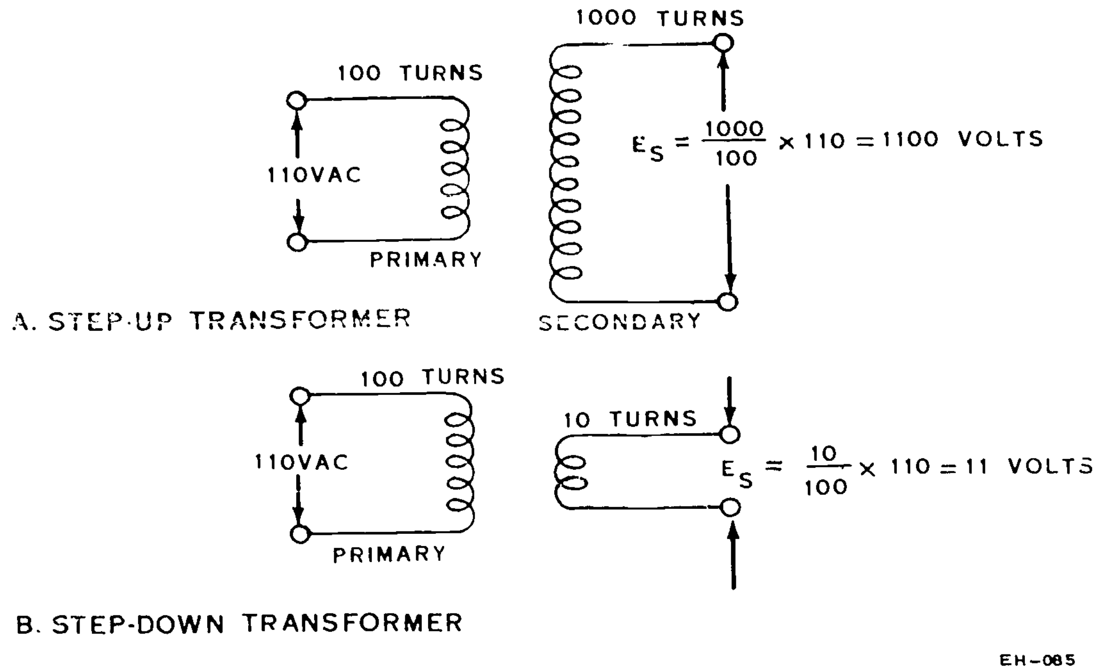


Figure 3–1. Step-up and step-down transformers.

Copper losses. Copper losses represent the power loss in resistance of the wire in the windings. These are called copper losses because copper wire is used for the windings.

Core losses. Core losses are due to eddy currents and hysteresis. The magnetic field which induces current in the secondary side also cuts through the core material, causing a current, known as eddy current, to flow through the core. These currents are like the swirls of water left behind a boat that is moving across a lake. Eddy currents heat the core material, a sign that power is being used. By making a core of thin sheets of metal insulated by varnish (laminating), the cross section of each current path is reduced, and the resistance to eddy current flow increases, thus reducing power losses.

Hysteresis losses depend on the core material used. Each time the AC current reverses in the primary winding, the field in the core reverses its magnetic polarity. A certain amount of power is required for this field reversal, resulting in a loss called hysteresis loss. To reduce hysteresis loss to a minimum, a material called silicon steel, which changes polarity easily, is used as the core.

*Power Factor*. In addition to the power losses we just discussed, there are other factors that affect the efficiency of a transformer. One is the inductance in the coil caused by the current lagging the voltage (out of phase) and the impedance of the transformers.

All these factors calculated together give us a rating known as power factor. Power factor is the ratio of the true power measured in watts of kilowatts (kW) to the apparent power measured in voltamperes or kilovolt-amperes (kVA). The power factor can be expressed as a decimal or as a percentage. Thus, a power factor of 0.8 is the same as 80 percent. Kilowatts are measured by the use of a wattmeter and will indicate real power or power which is available for work. Kilovolt-amperes are measured by the use of a voltmeter and ammeter and will indicate total effect on the circuit or apparent power. The formula used to find the power factor of an electrical component such as a transformer is:

$$\text{Power factor} = \frac{\text{kW true power}}{\text{kVA (apparent power)}} \text{ or } \left(\text{pf} = \frac{\text{kW}}{\text{kVA}}\right)$$

Multiply by 100 to get a percentage.

*Connections*. Transformer connections vary according to the type of transformer and type of system in which it is connected. You make different connections in order to meet the specific load demands of a particular or special circumstance.

You connect single-phase transformers according to the demand. You may connect them for lighting loads only or for combination lighting and power loads. If the demand is for a small lighting load only, you connect the secondary windings (which are the low-voltage windings) in parallel. The result is 120 volts for lights. As you know, if a greater load is drawn from a transformer than its rated load, the transformer will burn out. To be certain of having the correct transformer for the demand, you may use a formula

to convert into kilovoltamperes the apparent power from the transformer which is providing 120 volts for lights. This formula is

$$KVA = L = \frac{1 \times 120}{1000}$$

L represents the kVA load; I represents the current in amperes; and 120 is the amount of voltage. Current multiplied by voltage gives voltamperes and is expressed as such. You want to express the load in kVA, since the transformer is rated in kVA. You remember that the prefix "kilo" means thousand; by this method, you divide the voltamperes by 1000 to express the load in kVA. For example, in the formula used with a single-phase transformer which is connected so that it produces 120 volts for lighting, assume that the current available is 10 amperes. Use the formula:

$$kVA = L = \frac{10(I) \times 120(v)}{1000} = 1.2\ kVA$$

As mentioned previously, the transformer rating should equal the kVA of the demand. The load determines the size of the transformer required, but the power factor of the load determines the amount of usable power. The kVA placed into the system is greater than the kW which can be taken out of the system. Ammeters and voltmeters indicate total current and voltage regardless of the power factor, while the wattmeter indicates the effective product of the instantaneous values of voltage and current. A wattmeter indicates the true power. You have seen that a secondary connected in parallel provides single-phase service which meets the demands for lighting only.

A three-wire system makes it possible to serve both 120-volt lighting and 240-volt power loads at the same time. The transformer, as you remember, has two secondary windings, and, when the two secondary windings are connected in series, their voltages add; when the secondary windings are connected in parallel, their currents add. For example, if each secondary winding is rated at 120 volts and 10 amperes, the series-connection output rating will be 240 volts at 10 amperes or 2.4 kVA; the parallel-connection output rating will be 120 volts at 20 amperes, or 2.4 kVA.

*Types of transformers*. Transformers are classed according to service, purpose, method of mounting, and cooling. We are mainly concerned with the type of service and mounting. Power, distribution, and instrument are the main types you will use.

*Purpose of transformers*. The purpose of a transformer will determine how it is used in a circuit.

A constant-potential transformer is used to change the voltage of a system. Its primary is connected across a steady voltage supply and provides a steady secondary voltage which is the same from no load to full load. Power and distribution type transformers are of this type. The current in both the primary and secondary changes when the load is changed.

A varying-potential transformer is used to vary the secondary voltage when connected to a constant primary voltage. This type of service is what is found in a voltage regulator or a ballast for mercury-vapor lamps.

A current transformer is used to change the current of a system. Its primary winding is connected in series with the circuit in which it is desired to change the current. The voltage on both the primary and secondary will change with the change in current in the system. This type of transformer is used in instrument transformers.

A constant-current transformer is used to supply a constant secondary current to a system no matter what the load is. The primary is connected to a constant voltage but the secondary voltage will vary according to the load. This type of transformer is used a lot in series street lighting and airfield lighting systems. It is more commonly called a constant current regulator.

**Exercises (421):**

1. Explain the basic difference between a step-up and step-down transformer.

2. What are the four principal parts of a transformer?

3. What is the process by which a current is induced from one coil to another by use of an expanding and contracting magnetic field?

4. What type of transformer is normally oil cooled?

5. What is the secondary voltage of a transformer with a 10:1 turn primary operating on 240 volts?

6. Name the two types of transformer losses.

7. What material is used to reduce hysteresis loss to a minimum?

8. Solve for power factor of a transformer measuring 25.5 kW with apparent power measuring 30 kVA.

9. What type of power is indicated by a wattmeter?

10. Explain the relationship of voltage and current of two secondary transformer windings connected in parallel.

11. What is the purpose of an instrument transformer?

**422. Identify proper procedures for rating and connecting transformers.**

**Transformer Ratings.** Transformers are rated according to their voltage capacity and current-carrying capability. The voltage a transformer is able to carry is based on the insulation value of the coils and bushings. The current or amperage a transformer can carry is based on the size of the wire in the coils and the size of the terminal connections. The voltage and current are combined into a voltampere rating. When the VA rating is over 1000, the transformer ratings are expressed in kilovolt-amperes (kVA).

*Transformer data plate*. Every transformer should have a data plate mounted on the case to give you information concerning the operation and "hook up." See figure 3-2. The most useful information for us is the working voltages; that is, the primary or line voltage and load or secondary voltage. We will also need to know the maximum amperage capacity available. The data plate in figure 3-2 shows us that the transformer primary voltage is 430. The secondary voltage is 208 line to line, or 120 line to neutral. The capacity is rated at 150 kVA.

*Voltage taps and connections*. You may need to obtain a voltage different from that of the complete winding. To do this, most distribution and power transformers will have either taps or jumpers on the high-voltage windings. This allows a 10-percent increase of decrease in the supply voltage to be overcome, so that the rated secondary voltage can be obtained.

The data plate in figure 3-2 shows seven jumper connections on the primary winding which are used to maintain the proper voltage on the secondary winding. Notice that tap 3 is used for a 480 volt input. This would be your setting on a normal installation. If your primary voltage was above or below 480 volts, you would adjust the primary tap setting accordingly.

Figure 3-3 is the actual transformer the data plate (fig. 3-2) was taken from. You can see the three windings, the primary H terminals and secondary X terminals. Follow the H1 conductor to the right-hand coil. This point would be tap, or junction one on the data plate. We can determine this because it is the maximum length of coil H1. The remaining taps are staggered from left to right coming up the coil, with tap No. 7 on the top.

*Lead markings and polarity*. To get the proper connection of transformer coils and the connection of several transformers in parallel, a standard system of marking has been adopted by the various manufacturers. Practically all transformers have two windings on the secondary and may or may not have two windings on the primary. Marking always allows connection of either series or parallel circuits to obtain higher voltages or permits high-current draw at lower voltage.

Marking rules are as follows: All coil leads of the lower voltage windings, whether primary or secondary, are marked with the letter "X." All coil leads of the higher voltage windings are marked with the letter "H." For example, on a 240/120-volt stepdown transformer, the primary leads (240v) are marked "H" and the secondary leads (120v) are marked "X." However, on a 120/240-volt step-up transformer, the primary leads (120v) are marked "X" and the secondary leads (240v) are marked "H."

A numerical subscript follows the H and X markings, starting with No. 1 at one end of the winding and numbering the leads consecutively to the other end. Thus, the highest voltage across either winding would be from $H_1$ or $X_1$ to the lead of the highest subscript, provided that all of the individual coils are properly connected in series.

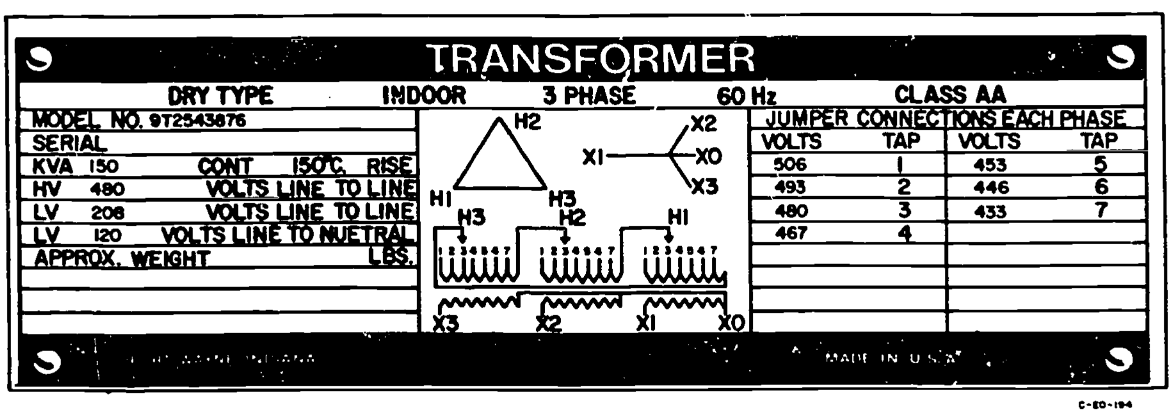


Figure 3–2. Transformer data plate.

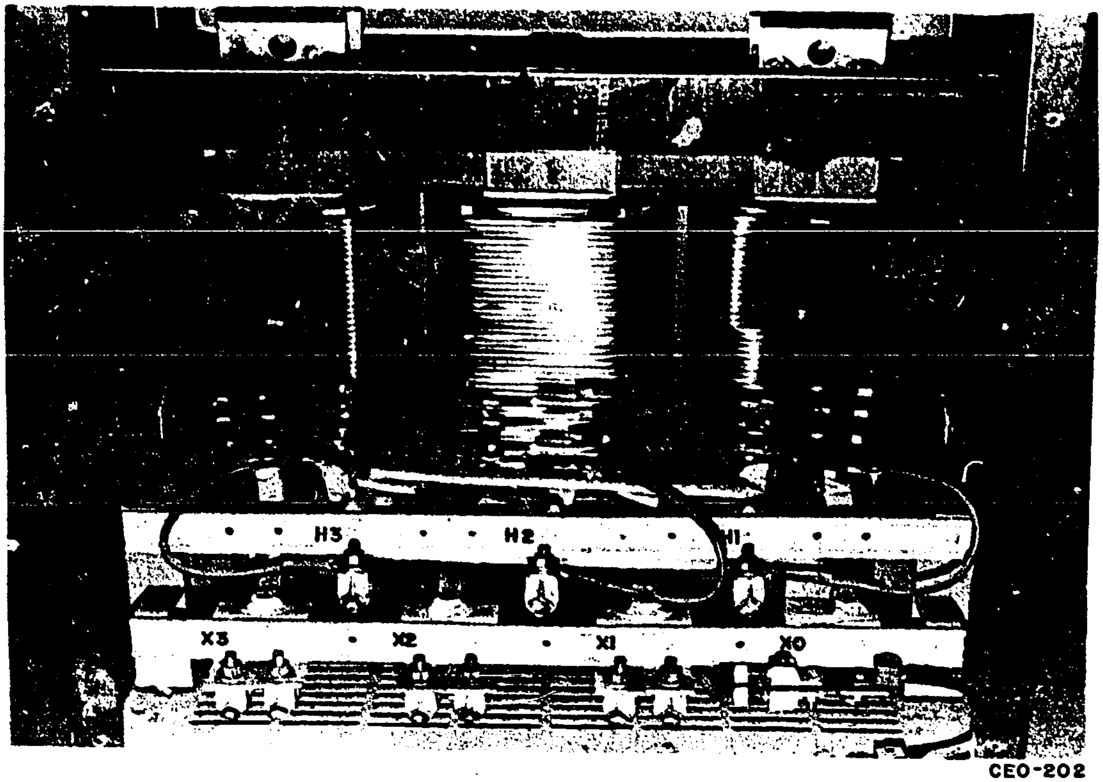


Figure 3–3. Three-phase dry transformer internal coils.

A definite instantaneous polarity relationship also exists between the primary and the secondary windings. In view of this, the windings are so marked that when $H_1$ is (+), $X_1$ is also (+); or, otherwise stated, when current flow is in at $H_1$, it is out at $X_1$. Observing these markings is especially important when connecting transformers in parallel or in three-phase systems.

**Exercises (422):**

Indicate whether each of the following statements is true or false by placing T or F in each blank. Correct false statements.

_____ 1. Voltage capacity and current-carrying capability are the normal ratings of transformers.

_____ 2. A transformer's current-carrying capability is based on the insulation value and size of the wire in the coils.

_____ 3. The most useful information on a transformer dataplate is the working voltages.

_____ 4. Transformer taps or jumpers are connected on the low voltage windings to regulate the secondary voltage.

_____ 5. Transformer marking rules require all primary connections to be marked with the letter "H."

**423. State pertinent facts concerning the installation and connection of transformers and state inspection and maintenance procedures that reduce transformer failure.**

**Installation and Connection.** When installing or replacing a new single-phase or three-phase transformer, you should be concerned with the requirements in Article 450 of the National Electrical Code.

When installed, a transformer shall be readily accessible to qualified personnel for inspection and maintenance. This means that transformers shall be secured in a vault or areas so only personnel who work with the system can obtain access.

Like all electrical equipment, transformers must have some form of overcurrent protection. Each transformer that operates at 600 volts or less shall be protected by an individual overcurrent device on the primary side, rated or

set at not more than 125 percent of the rated primary current of the transformer. For example, if we were installing a transformer with a primary current of 100 amps, the overcurrent device should be 125 amps maximum. Sometimes it is not feasible to install an overcurrent device on the primary of a transformer. In this case, an overcurrent device can be installed on the secondary as long as it does not exceed 125 percent of the secondary current. This is a legal installation only if the primary feeder overcurrent device is rated or set at a current value not more than 250 percent of the rated primary current of the transformer. For example a 150 kVA transformer has a current rating on the primary of 180 amps and a secondary current rating of '16 amps. If the transformer was installed as stated above, the overcurrent device on the secondary should not exceed 520 amps as long as the primary feeder overcurrent device does not exceed 450 amps.

Transformers installed indoors fall into two sections, above 112½ kVA rating and below 112½ kVA. Transformers rated less than 112½ kVA must be installed at least 12 inches from combustible material unless separated by a fire-resistant, heat-insulating barrier or completely inclosed except for ventilating openings. Transformers of more than 112½ kVA rating shall be installed in a transformer room of fire-resistant construction. Dry-type transformers installed outdoors shall have a weatherproof inclosure.

There are many other requirements when installing transformers. To insure the proper installation, electricians should also follow requirements for grounding, inclosure, and conductors in accordance with the National Electrical Code.

*Single-phase.* Transformer connections are very important. Before connections can be made, you should identify the primary and secondary windings. Transformer nameplates are usually marked to indicate connection procedures of the transformer windings. High-voltage leads of a transformer are marked with an H, and the low-voltage leads are marked with an X.

*Three-phase.* The connection of a three-phase transformer requires the same procedures as a single-phase transformer, except that the electrician must be aware of the 3 or 4 wire system. Three-phase transformer windings will be connected in one of the following manners, depending on the needs of the facility.

- Primary is delta and secondary is delta.
- Primary is wye and secondary is wye.
- Primary is delta and secondary is wye.
- Primary is wye and secondary is delta.

*Delta-delta connection for power only.* The connection shown in figure 3-4 has been used a lot to supply three-phase power. It is called a delta-delta connection. The primary and secondary are in a delta configuration. You will note that each transformer is connected to two of the phases both in the primary and secondary. Ground one of the midtaps for your safety and protection of the equipment.

*Delta-delta connection for light and power.* When light and power are to be supplied from the same bank of transformers, the midtap of the secondary of the middle

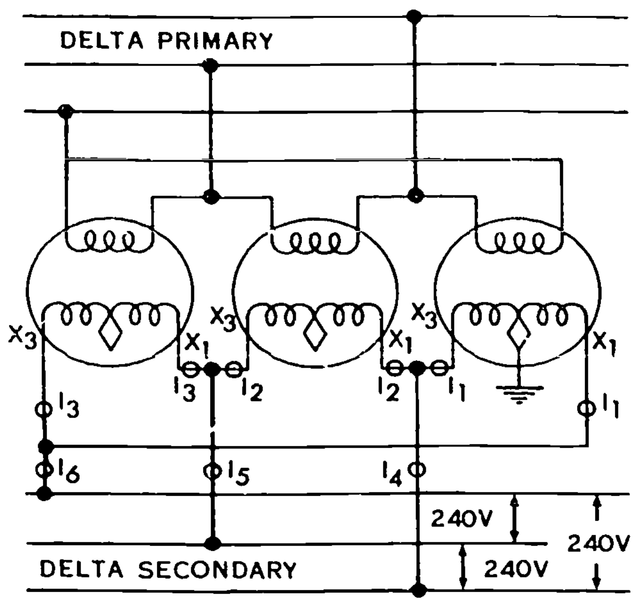


Figure 3-4. Delta-delta connection for power.

transformer is grounded and connected to a fourth wire of the three-phase secondary system, as shown in figure 3-5. The lighting load is then divided between the two hot wires of this same transformer, the grounded wire being common to both branches. This type of connection is used when the powerload is more than 60 percent of the total load on the bank. You will note that the voltage as measured between A and N is higher than B to N or C to N. Phase A is called the wild, or stinger, leg. This is an unusable voltage. Connecting 120-volt equipment to A phase and neutral will cause it to operate improperly, with the likelihood of extensive damage to the equipment. Where the lighting load is large, the transformer that the neutral is tapped off of should be proportionately larger than the other two transformers.

*Delta-wye connection.* In all banks mentioned before, which serve light and power on the secondary, the grounded secondary wire is not the neutral of the three-phase system but is the midpoint of one leg of the delta. Furthermore, all the lighting load is put on two of the three phases; thus, the primary currents in any bank are unbalanced. In the delta-wye connection, figure 3-6, the neutral of the three-phase secondary system is grounded.

The single-phase loads are connected between the different phase wires and neutral. The three-phase powerloads are connected to the three-phase wires. Thus, 120 volts is supplied to the lighting load and 208 volts to the powerload. With this type of bank, the single phase in each bank by itself and the secondaries of different banks can be tied together. The 208 volts is obtained by multiplying the phase voltage (120) times 1.732. This will produce 208 volts, or the line voltage as measured from phase to phase.

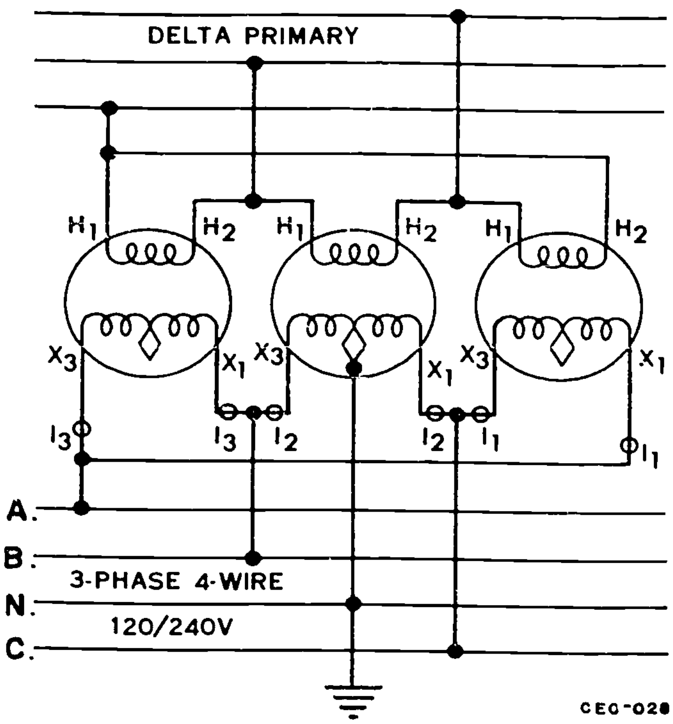


Figure 3–5. Delta-delta connection for both power and light.

*Wye-wye connection for light and power.* The primaries of the transformers can also have a wye connection, as shown in figure 3-7. When the distribution feeder voltage is four-wire wye, transformers having primary winding of the phase-to-neutral voltages are used. The primary neutral must be available and tied solidly (bonded or banded) with the secondary neutral of the bank. If the three-phase load is unbalanced, the neutrals carry the unbalanced current. The neutrals must remain solidly connected and grounded to stabilize voltage and dispose of third harmonic voltages which appear in the event of an open neutral connection.

*Wye-delta connection for light and power.* The wye-delta connection is often used for light and power when more than 60 percent of the total load is power. This bank can be used even when the primary neutral is not available. The neutral is floated to prevent two transformers from functioning as an open delta bank in the event one transformer fails. See figure 3-8. The main disadvantage of this hookup is that full load current flows in the neutral, even though the three-phase load may be balanced. This type of bank is satisfactory when the main part of the load is power and the single-phase load is small.

**Inspection and Maintenance.** As with any other electrical equipment, sometimes we have transformer failures. In the hope of preventing or reducing failures of transformers, we must periodically inspect and perform maintenance on them.

A transformer needs less care than any other type of electrical apparatus, because it does not have any moving parts. Since no lubrication is required, many operating and maintenance problems are eliminated. As a result of this,

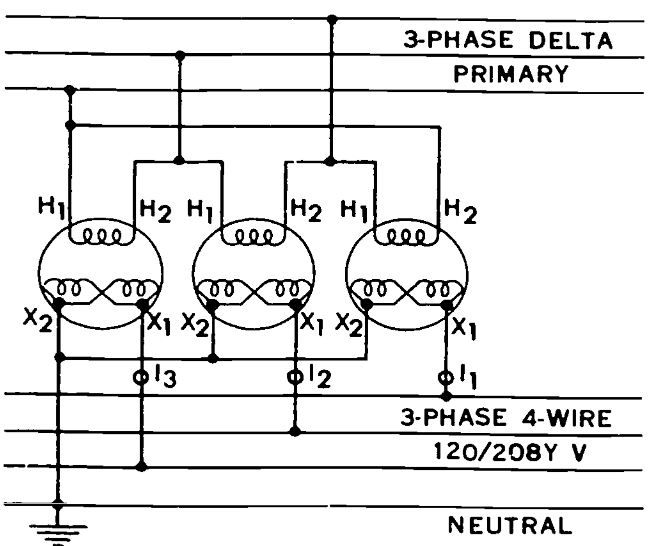


Figure 3–6. Delta-wye connection for power and light.

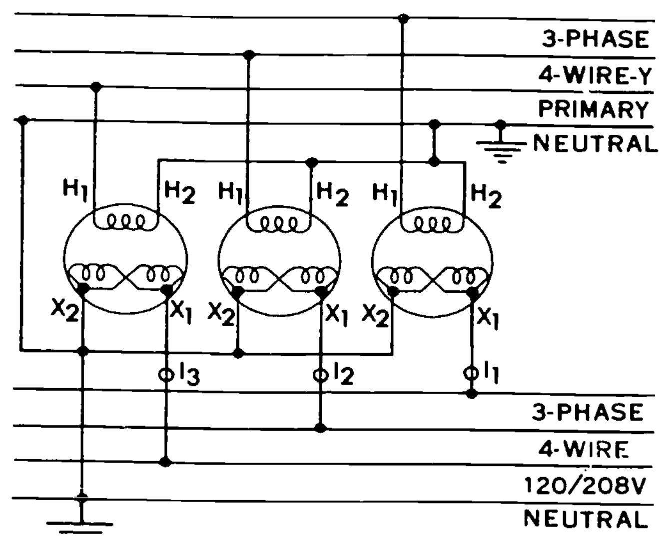


Figure 3–7. Wye-wye connection for power and light.

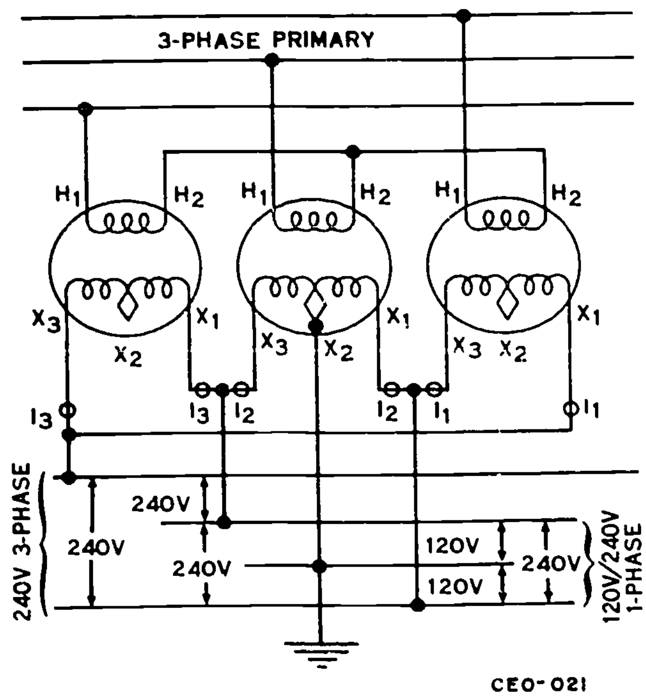


Figure 3–8. Wye-delta connection for power and light.

transformers are likely to be neglected. However, neglect of certain fundamental requirements may lead to trouble and even to failure of the transformer.

For minimum maintenance expense, careful inspection of transformers is necessary. No matter how satisfactory the operation of a transformer may be, it is a good plan to take the transformer out of service and thoroughly inspect it every few years. All nuts and bolts should be checked to see that mechanical parts are tight and that all parts are in their proper places.

Electrical connections should be checked and kept tight to prevent overheating. External parts must be kept painted. The area around and inside the transformer should be kept as clean as possible.

Your inspection and maintenance steps must insure accessibility of the transformer at all times. There should not be any foreign items stacked on top of or around the outside of the transformer. Airflow could be restricted and cause increased heating of the transformer.

The final step in transformer maintenance is taking a voltage reading under load and adjusting the tap setting for the voltage specified on the data plate.

**Exercises (423):**

1. What size overcurrent device is required on the primary side of a transformer with a rated primary current of 50 amps?

2. What maximum size transformer mounted indoors must be installed at least 12 inches from combustible material?

3. What are the two types of three-phase transformer connections?

4. What three-phase transformer bank has a wild, or stinger, leg containing unusable voltage on 120-volt equipment?

5. What three-phase transformer bank has the disadvantage of full load current flowing in the neutral, even though the three-phase load may be balanced?

6. How often should you take a transformer out of service and thoroughly inspect it?

7. Why should you check nuts and bolts when the transformer is out of service?

8. Why should you check electrical connections when the transformer is out of service?

**424. State common problems and instruments used for troubleshooting transformers.**

**Troubleshooting Transformers.** Since transformers are an essential part of the equipment you will work with, you should know how to test and locate troubles that develop in transformers. The three things that cause transformer failures are open windings, shorted windings, and grounds.

*Open windings.* When one of the windings in a transformer develops an "open," no current can flow; and the transformer will not deliver any output. An open is actually a break in the continuous path of an electrical circuit. The symptom of an open-circuited transformer is that the circuits which derive power from the transformer are dead. A check with an AC voltmeter across the transformer output terminals will show a reading of zero volts. A voltmeter check across the transformer input terminals shows that voltage is present. Since there is

voltage at the input and no voltage at the output, you conclude that one of the windings is open.

An open in a transformer can also be located by using an ohmmeter. After disconnecting all of the primary and secondary leads, each winding is checked for continuity, as indicated by the resistance reading taken with an ohmmeter. An indication of a fairly low resistance reading shows a good winding. A reading of infinity indicates an open winding.

*Shorted windings*. When a few turns of a secondary winding are shorted, the output voltage drops. The symptoms are that the transformer overheats due to the large circulating current flowing in the shorted turns and that the transformer output voltage is lower than it should be. The winding with the short gives a lower-than-normal reading on the ohmmeter. In the case of a partial short, you can best determine the trouble by replacement if the other steps already mentioned fail.

Sometimes a winding has a complete short across it. Again, one of the symptoms is excessive overheating of the transformer due to a very large circulating current. Also, there will be no voltage output across the shorted winding, and sometimes you may have a tripped overcurrent device or blown fuse. If the overcurrent device does not blow, the transformer's winding may burn out. There are three types of shorts you should look for:

(1) Shorted primary.
(2) Shorted secondary.
(3) Shorted primary to secondary.

*Grounded windings*. Sometimes the insulation at some point in the winding breaks and the wire becomes exposed. If the bare wire is at the outside of the winding, it may touch the inside of the transformer case, shorting the wire to the case and grounding the winding. The symptoms are excessive overheating and no voltage output. You can check for a transformer ground by connecting the megger between one lead of the winding in question and the transformer case. Make sure all leads have been disconnected from the circuit. A zero or low reading on the megger shows the winding is grounded.

**Exercises (424):**

1. Name three troubles that could occur in a transformer.

2. Explain an open winding.

3. If you have voltage at the input of a transformer but no voltage output, what trouble is indicated?

4. Besides a voltmeter, what other meter could you use to locate an open in a transformer winding?

5. What effect will a few turns of the secondary shorted together have on the output voltage?

6. Explain a ground.

7. What type of meter should you use to check for a ground?

## 3-2. Regulators

The components of many items of electrical and electronic equipment, such as computers, timeclocks, precision measuring and testing devices, alarm systems, and communication equipment, must have a constant-voltage power source for proper operation. Voltage-regulated power supplies have been developed to supply the many needs for constant-voltage power sources.

**425. Restate the specific features and characteristics of a basic saturable reactor and voltage regulator.**

**Voltage Regulators.** Just as there are many applications for voltage-regulated power supplies, so there are several methods of achieving this regulation. Each method is designed to meet a specific application. For example, one basic voltage regulator circuit may be quite useful because it is simple, but it may be less efficient than another type at high operating load currents. Conversely, a relatively efficient regulator circuit may contain too many circuit components to be practical when the ultimate in voltage regulation is not required.

*Principles of voltage regulation*. Many types of electrical and electronic equipment must be operated from a source of constant voltage for proper operation. A typical power supply, in most cases, is not capable of providing this constant voltage, ror two basic reasons:

(1) The output of the supply will vary if the line voltage varies. Hence, if the line voltage increases, the power supply output voltage will also increase.

(2) Various components within the power supply itself, such as transformer and filter choke winding resistances and the voltage drop of the rectifier, produce internal impedance of the power supply. We may consider this impedance as a simple resistor in series with the output terminals of the supply. Thus, as in any series circuit containing resistance, when the load current increases, the output voltage decreases.

Voltage regulation is used to compensate for these causes of voltage variation, and you can easily do this with the use of either a shunt or series regulation.

*Shunt voltage regulation*. Figure 3-9 shows the basic shunt voltage-regulator system. As you can see, the shunt regulator element, $R_1$, and its series resistor, $R_2$, form a voltage divider which is connected across the output of the unregulated supply. The external load is connected across the shunt regulator.

Let's imagine for a moment that the external load current increases. This will result in a decrease in the voltage across the load. Assuming for a moment that the shunt regulator element, $R_1$, can be varied manually, we can bring the voltage across the load up to normal by increasing the resistance of the shunt regulator. This will decrease the current through $R_2$ and the shunt regulator element, which will result in a smaller voltage drop across $R_2$. This, in turn, will increase the voltage applied to the load.

A decrease in load current will cause an increased voltage across the load, which can be compensated by decreasing the resistance of the shunt regulator element, $R_1$. This will cause a greater current flow through $R_2$ and the shunt regulator element, which will drop the voltage appearing across the load.

*Series voltage regulation*. The basic series voltage regulator is shown in figure 3-10. Here, the regulator element is placed in series with the load, so that its resistance will determine the voltage applied to the load as in the case of any series circuit.

Let us say for a moment that the external load decreases; that is, the load impedance has increased. This will result in an increase in voltage appearing across the load because of a decrease in voltage drop across the series regulator element. We can bring this voltage back down to its original value by increasing the resistance of the series regulator, thereby increasing the voltage drop across it.

By the same token, a decrease in voltage across the external load terminals, as caused by an increase in load current (decrease in load impedance), can be corrected by decreasing the resistance of the series regulator.

Of the two basic voltage regulators, shunt and series, the series is the most efficient. The shunt regulator must dissipate power in both its regulator element and series-dropping resistor, whereas the regulator element alone dissipates power in the series regulator. The shunt regulator represents an additional current load in parallel with the load it is regulating. This, of course, increases the current requirements of the unregulated power supply. The series regulator requires only a series regulator element in series with the unregulated power supply.

Basically, there are three types of voltage regulators: (1) the vacuum-tube type, (2) the semiconductor type, and (3) the magnetic amplifier type. The vacuum-tube and semiconductor types of voltage regulators are used for electronic circuits and are used in low current applications. We talked about them in Volume 2 of this CDC. We will talk about the magnetic amplifier, because it is the type of equipment that an electrician in the Air Force may encounter.

**Magnetic Amplifiers.** The magnetic amplifier or saturable reactor, as it may be called, is a control or regulating device that has a core, usually donut or square in shape. Most magnetic amplifiers have some type of DC control winding and an AC load winding. In most of the basic amplifiers, two windings are all that are used. When you get to some of the more advanced systems, you will see more than two windings, but for now use the basic system.

*Simple saturable reactor*. In figure 3-11 a simple saturable reactor is shown. As you can see, it has two coils: the control winding and the load winding. The load is connected in series with the load winding and has an AC source. The control winding is used to saturate the iron core and acts as the controlling factor of the unit.

The inductive reactance of the coil is proportional to the amount of flux produced by the current in the coil. In figure 3-11 a low flux level is set up in the iron core by the direct

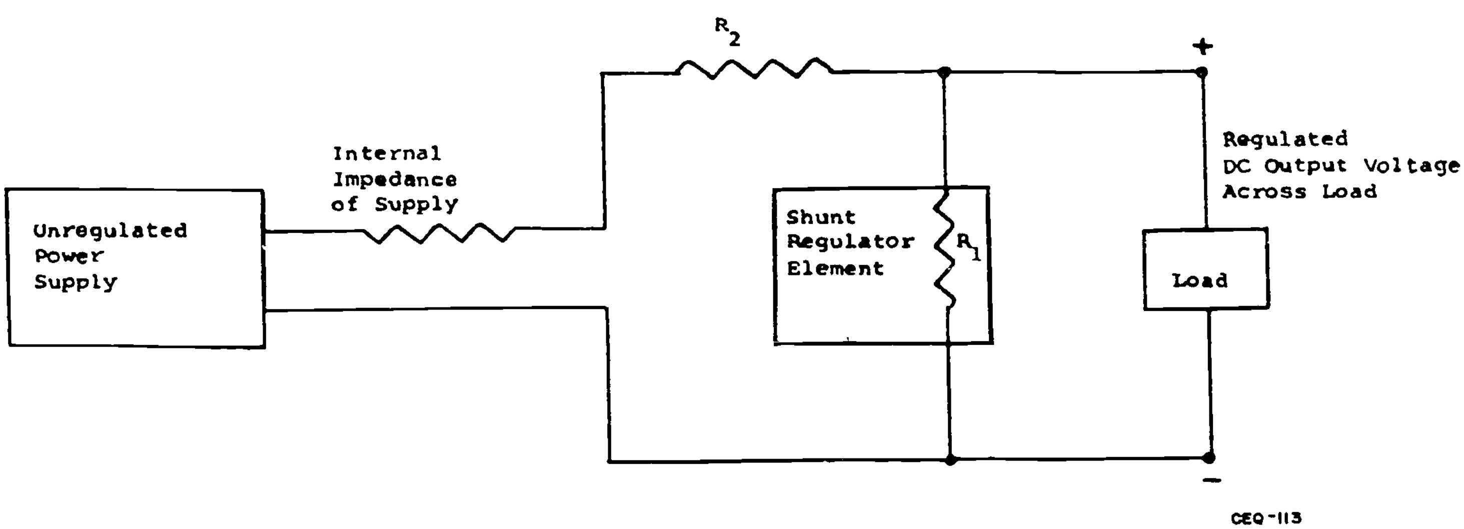


Figure 3–9. Basic shunt voltage regulator system.

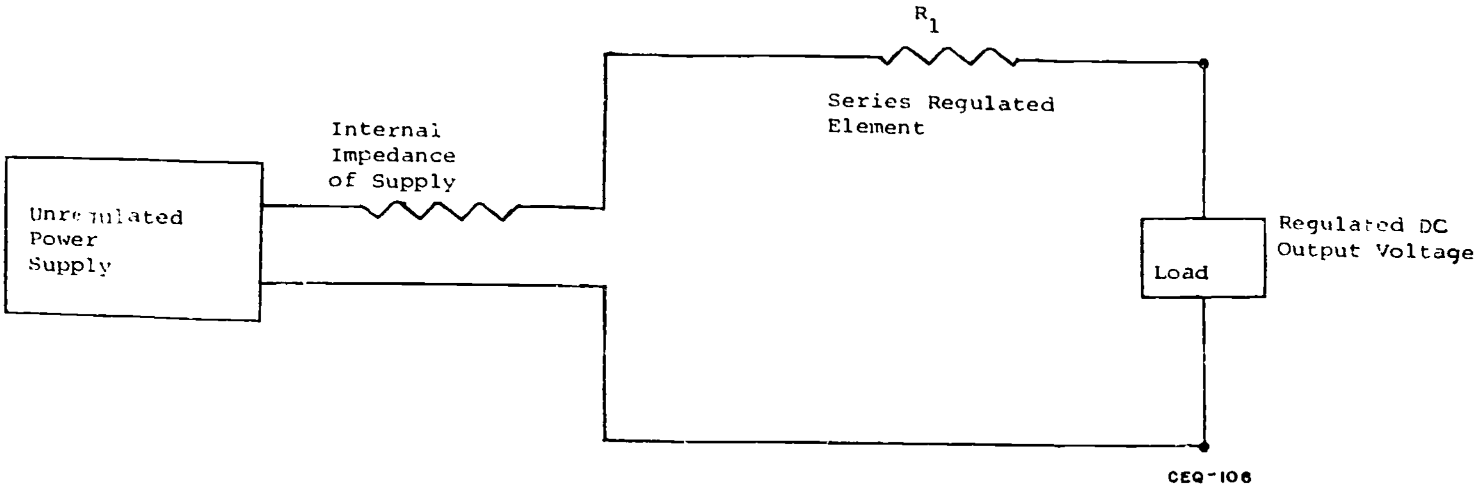


Figure 3–10. Basic series voltage regulator system.

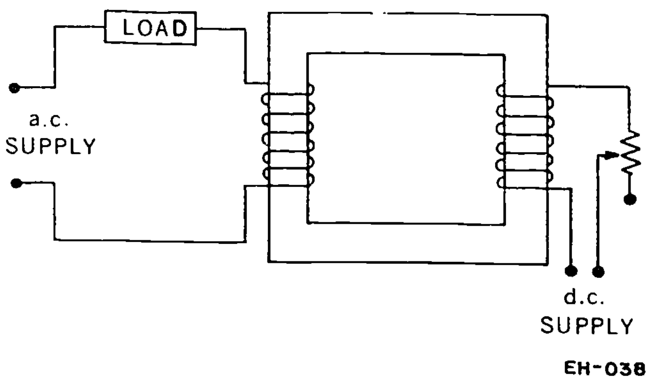


Figure 3–11. Simple saturable reactor.

current in the control winding. When this is the case, the flux produced by the AC in the load coil is high, because the load current does not produce enough flux to saturate the core alone. Thus, the inductive reactance of the AC coil (which is measured opposition) is very high, and the current in the load winding is very low.

If the current in the DC circuit is increased to a point where it produces enough flux to saturate the core, the current in the load coil is able to produce little additional flux and the coil has a low inductive reactance. Therefore, the resistance of the load coil is primarily limited to its resistance, and there is maximum current through the load.

It is apparent, then, that the flux level set by the control winding can regulate the AC current in the load. Since the control coil flux is proportional to its ampere-turns, only a small amount of DC is necessary for control when a control coil of many turns is used.

*Balanced saturable reactor*. In figure 3-11, AC in the load coil induces an AC voltage in the DC control coil. The resultant AC in the DC circuit causes heating of the control coil. This is wasted power. Also, the control coil always contains a large number of turns, which causes the voltage induced in it to be extremely high. This voltage could arc between the turns of the coil and destroy the insulation. By using the balanced configurations in figure 3-12, no voltage is induced in the control coil, thus avoiding the problem just mentioned. With this balanced circuit, the flux produced at any instant in the control coil by one load coil is nullified by flux of the opposite direction from the other load coil. Figure 3-13 shows the magnetic amplifier being used as a dimmer for theater lamps. It is using a three-legged reactor core to control the lights. Now that we have talked about a saturable reactor, let us see how it works when used as a voltage regulator.

*Magnetic amplifier voltage regulator*. As you know, a transformer operates on the principle of magnetic induction. Magnetic lines of flux are induced in the iron core and thus into the secondary winding when current is applied to the primary winding. The amount of energy transfer between primary and secondary depends to a great extent upon the ability of the core to conduct these magnetic lines of force.

Ordinary transformers are constructed in such a way that the magnetic path between primary and secondary windings is always as good as possible. On the other hand, a magnetic amplifier, sometimes known as a satuable reactor, is so constructed that the magnetic path between the primary and secondary may be controlled as desired. The ability to control the energy transfer between primary and secondary windings is the basic principle of the magnetic amplifier. If a third winding is placed on a magnetic amplifier, as shown in figure 3-14, energy reaching the secondary will depend upon the current passed through the third winding.

The DC control current flowing in this third winding can cause a change in energy transfer between primary and secondary windings. This is due to an effect known as core saturation. As the amount of DC increases, so does the amount of flux, until a point is reached at which an increase in DC can cause no further flux increase. The core is then

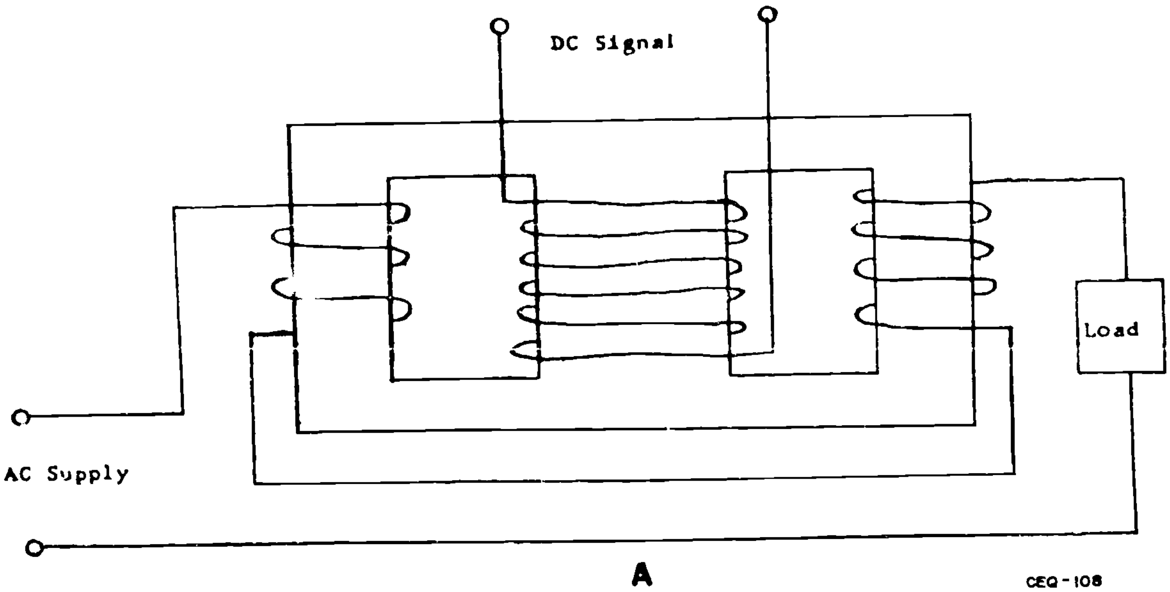


Figure 3–12. Balanced saturable reactor.

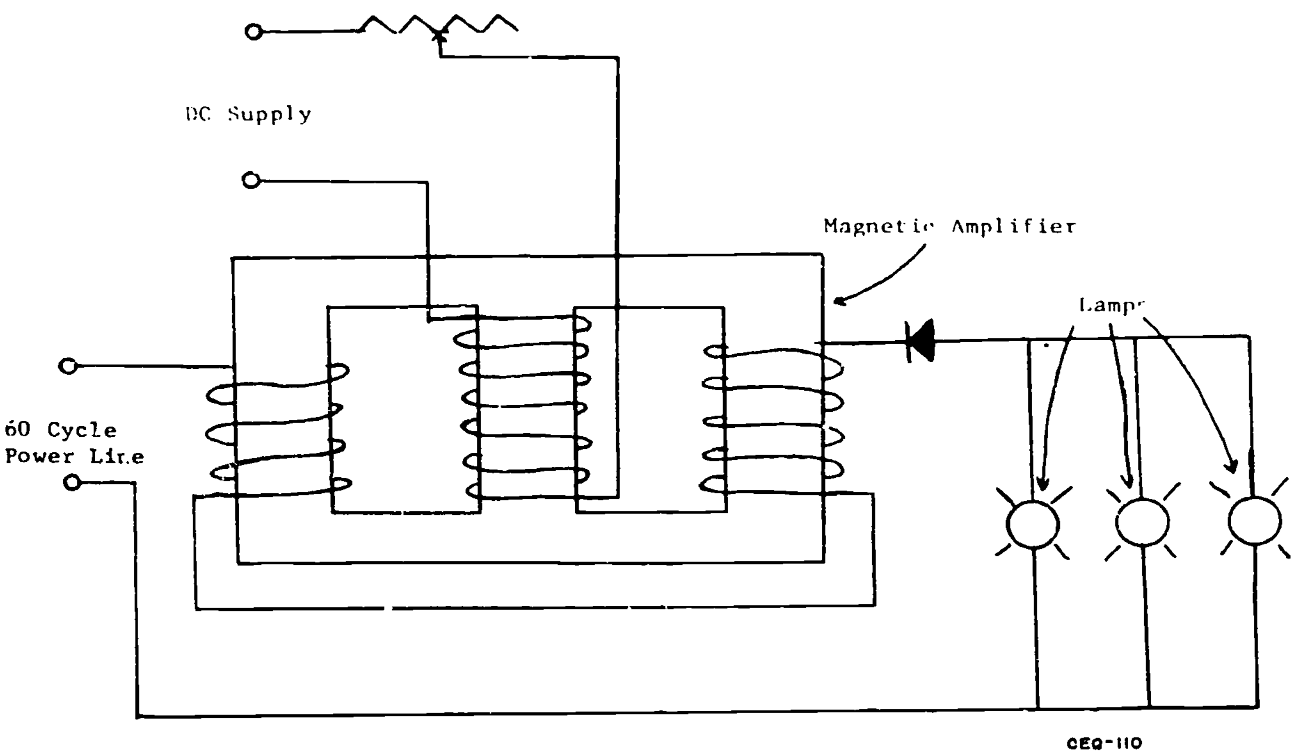


Figure 3–13. Theater lamp dimmer.

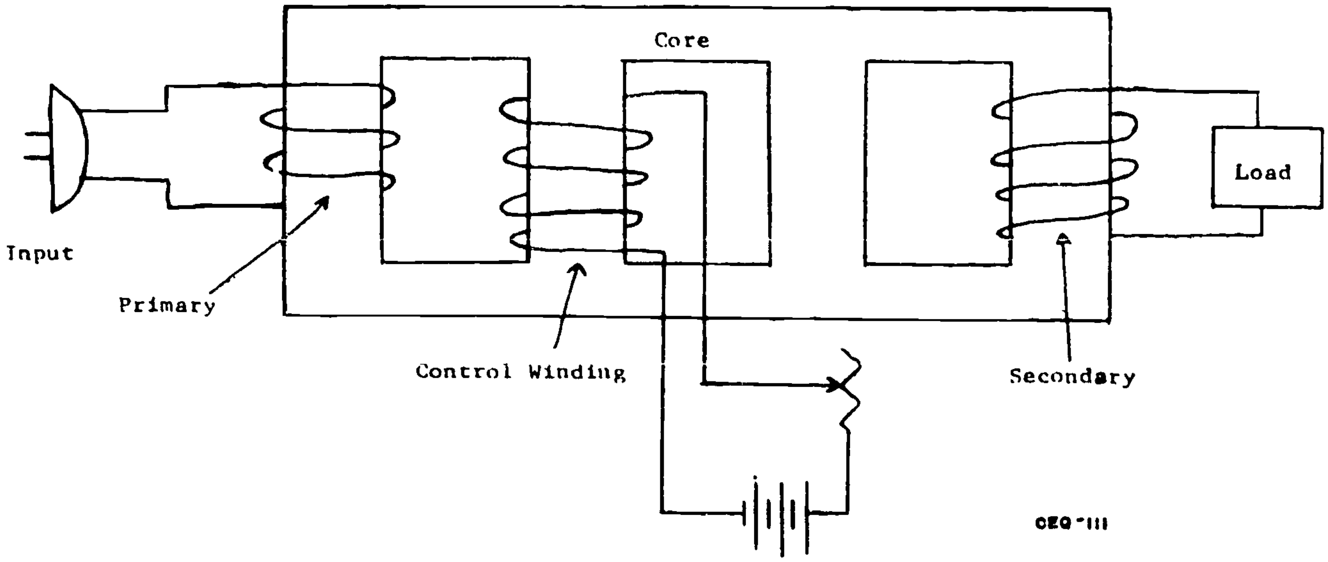


Figure 3–14. Basic circuit of a magnetic amplifier.

said to be saturated. When the core is fully saturated, practically no energy can be transferred between primary and secondary windings.

Magnetic amplifiers are extremely useful for several reasons. First, they are very rugged mechanically. Second, they are capable of continuous operation for extended periods of time without attention or service. Third, magnetic amplifiers can handle very large amounts of power.

Because of their ability to control large amounts of power, you will find magnetic amplifiers used in such applications as theater light-dimming controls, where they can replace the high-wattage, high-heat dissipation rheostats. They are also used in the control of large motors by means of relatively small AC control signals.

*Use of the magnetic amplifier as a voltage regulator.* Figure 3-15 shows the circuit of a magnetic amplifier used as a voltage regulator. The magnetic amplifier output voltage is sampled to obtain an error signal corresponding to variations in load voltage. This error signal is amplified by an error signal amplifier and compared with constant-voltage reference. The resulting correction signal is used to control the current flowing in the magnetic amplifier control winding.

Let us say that the regulator output voltage drops as a result of an increasing load current. This drop in output voltage will be sensed by the error-sensing network and applied to the error-signal amplifier. After being compared with the constant-voltage reference, the resulting signal will be of correct polarity to decrease the current flowing in the control winding. This will decrease core saturation and allow more voltage to be developed in the secondary winding, thereby increasing the regulator output voltage to its normal value.

Another method for compensating line voltage variations is to use a transformer which operates with its core nearly saturated at all times. Under these conditions, an increase in input line voltage causes virtually no change in secondary voltage. Since the core is already nearly saturated, an increase in input voltage can cause essentially no further current to be induced in the secondary winding.

One bad feature of the magnetic amplifier as a voltage regulator is that rather severe waveform distortion often takes place as the core goes into saturation. This distortion can cause difficulty when certain types of equipment, such as test equipment, are operated from this type of regulator. The distorted waveshape generates large amounts of harmonics which can appear at the output of the test equipment internal power supply, then be radiated to various sensitive circuits within the instrument, and there cause errors in calibration, etc.

**Exercises (425):**

1. An increase in the external load current will result in a decrease in the ____________ across the external load.

2. Why is a series voltage regulator more efficient than the shunt?

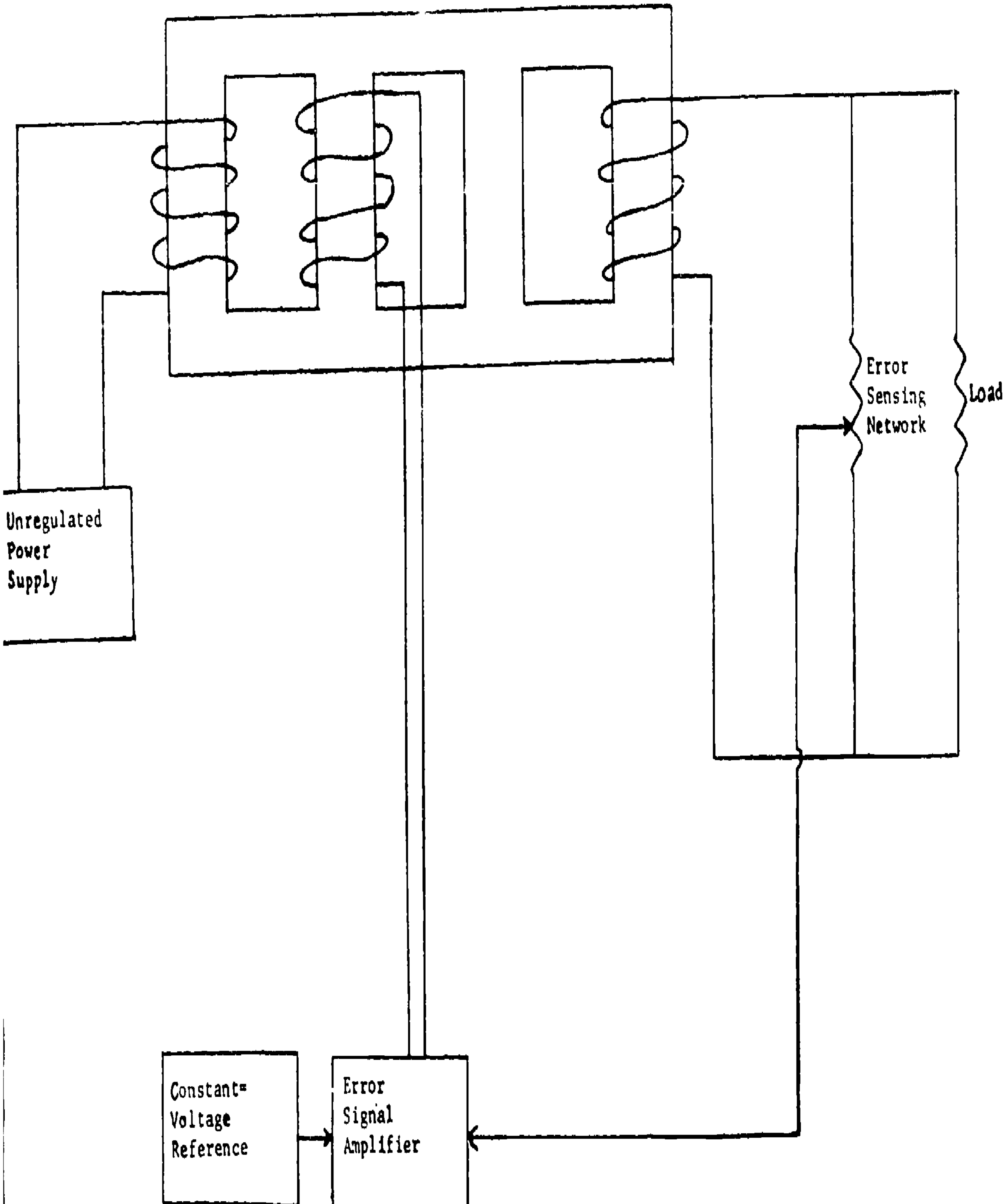




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Figure 3-15. Basic magnetic amplifier regulator circuit.

3. The basic magnetic amplifier has __________ windings.

4. At what point in its operation is a core considered saturated?

5. Where can a magnetic amplifier be used?

6. What is one bad point about a magnetic amplifier?

**426. Restate procedures about the installation, inspection, maintenance, and troubleshooting of voltage regulators.**

**Selecting the Proper Voltage-Regulated Power Supply.** There may be occasions when you will be called upon to choose a regulated power supply for a specific application. It is, therefore, important that you have an understanding of the various ratings used in the evaluation of regulated power supplies.

The most important requirement of a voltage-regulated power supply is that of maintaining an essentially constant voltage under various load conditions. The regulating ability of the supply is generally given as a percentage of voltage change from no load to full load. For example, a particular supply might be rated as having 1 percent regulation from no load to its rated full-load current of 200 amps. If the supply has a voltage rating of 300 volts, for example, its output voltage will not vary more than 3 volts at any current from 0 to 200 amps. In general, percent regulation is given by the formula:

$$\frac{\text{No Load Voltage} - \text{Full Load Voltage}}{\text{Full Load Voltage}} \times 100$$

Since regulated supplies also correct for changes in input line voltage, they are also rated in percentage of output voltage change for a specified change in input line voltage. Thus, a 300-volt supply with 1-percent regulation for line voltage changes of from 95 to 125 volts will provide an output voltage which will vary not more than 3 volts for any input line voltage ranging from 95 to 125 volts.

**Installation and Connecting.** To insure proper installation and connection, the electrician must consult the manufacturer's requirements and the National Electrical Code. No specific code articles have been written concerning voltage regulators, so just follow articles concerning installation and connection of equipment.

**Inspection and Maintenance Procedures.** Voltage regulator systems require little maintenance. About the only inspection that you, as an electrician, can do is check and see that the voltage is being maintained as required by the system. You should also keep the equipment free of dirt and lint, and provide proper ventilation.

Troubleshooting and Repairing/Replacing Procedures. Voltage regulators are pretty much trouble free. You could not say that one area was weaker than another. Troubleshooting will consist of checking for the required voltage at the output terminals. If the proper voltage is not present, the electrician should consult manufacturer's data for proper troubleshooting techniques. If a faulty component is identified, it must be either replaced or repaired, depending on the component. In most cases, the component or components cannot be repaired and must be replaced.

**Exercises (426):**

1. When selecting a voltage regulator, what requirements must be followed?

2. Explain what type of inspection you would perform on voltage regulators.

3. Identify some maintenance ideas that would provide proper operation of a voltage regulator.

4. In a series voltage regulator system, the regulating resistor has opened up. What voltage would you expect to find across the external load terminals?

5. If you were called upon to troubleshoot a magnetic amplifier and you found it defective, what would you do?

## 3-3. Battery Banks and Changers

Batteries! How often do you depend on a battery for some function during your day? Batteries are a very important part of our everyday lives. They start our cars, they run our flashlights, and even run our watches. We can also join them together into a battery bank and use a charger to recharge them when they are low.

**427. Explain the operation of a basic battery in terms of composition, cell type and connection, installation procedures, and voltage capacity.**

**Batteries.** There are two basic types of batteries, and both of them produce electricity from chemical action. They are either primary cells or secondary cells. The primary cell, once it is run down, is of no more use. A secondary cell can be restored for use by passing a current through it in the reverse direction. This process is known as charging. Since secondary cells can be used and then recharged, they are called storage batteries. Remember, however, that no battery stores electricity; it is a chemical unit that under the right conditions will produce an electromotive force (emf).

The symbols used in diagrams of electric circuits for a battery are shown in figure 3-16. Symbol A shows a single cell battery; symbol B, a multicell battery; that is, a battery made up of more than one cell. It is usual to identify the long line of the symbol as the positive terminal and the short line as the negative post. Like symbols are used for both primary and secondary cells.

*The primary cell.* If two different metals are placed within a chemical solution called an electrolyte, electrical activity will result when the metal electrodes (called plates) are joined through an electric circuit. The voltage created will depend solely upon two factors: (1) the material from which the plates are made and (2) the type of electrolyte used.

Primary cells are almost always of the dry type. In a dry cell, an absorbent material is saturated with the electrolyte and is then placed in contact with the plates. The advantage of the dry cell is that the casing is sealed to prevent the electrolyte from spilling out of its container. Note however, that a dry cell is in no sense actually dry, since the electrolyte is a gel-like substance.

An ordinary dry cell is made up of a zinc case or container and a carbon rod (placed within it, but not contacting the zinc at any point) acting as the positive plate. The electrolyte is a solution of ammonium chloride, which saturates an absorbent that fills the container. Between the zinc and the saturated absorbent material is a cardboard layer (blotter) that acts as an insulator, separating the zinc from the other elements, but allowing chemical action to occur, since it also becomes saturated with the electrolytic solution. See figure 3-17.

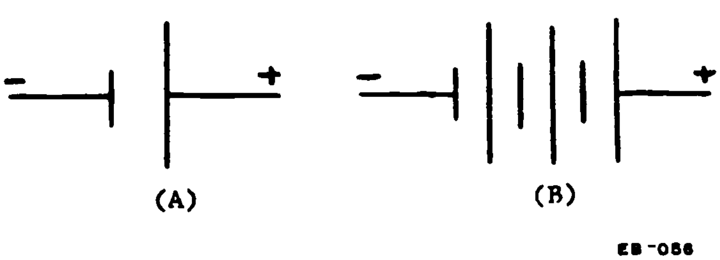


Figure 3–16. Battery symbols.

When the terminals of a dry cell are connected to an electric circuit, the ammonium chloride electrolyte ionizes to form ions of ammonium and chloride, the former bearing a positive charge and the latter a negative charge. Positive ions escaping from the zinc plate leave the zinc with an excess of electrons. This leaves the zinc plate negatively charged.

At the same time, the positive zinc ions are repelling the ammonium ions, which are also positively charged, and under this influence, the ammonium ion breaks up into hydrogen ions (bearing a positive charge) and ammonia gas. The hydrogen ions are repelled toward the carbon plate, giving it a positive charge. When a conducting path exists between the negatively charged zinc plate and the positively charged carbon plate, the negative electrons on the zinc plate are attracted by the positive charge on the carbon. This results in a current flow from the negative terminal through the electric circuit to the positive terminal of the cell.

Each zinc-carbon dry cell can deliver an emf of 1.5 volts when it is fully charged. The voltage does not depend upon the size of the cell, but the amount of current it can supply is directly dependent on the size. Thus, dry cells, such as are used as flashlight batteries, are quite small, whereas those used for heavier current drains are larger.

*Secondary cell.* The most outstanding advantages of the storage or secondary cell over the primary cell are that:

*a.* It can be recharged.
*b.* It can be built to provide greater current capacities.
*c.* It is more economical in the long run.

Since the storage battery is more economical to operate, it is used predominantly in automobiles, airplanes, telephone exchanges, and other places where DC must be supplied.

*Lead-acid batteries.* The most common storage battery is the lead-acid battery. The name comes from the fact that the plates are made of lead, and the electrolyte is sulfuric acid. See figure 3-18. The positive plates in this battery are made of lead peroxide. The negative plates are made of sponge lead. All of the plates are separated from each other by some insulating material, such as glass, which is called a separator. These plates are connected together and placed in a container with a separate compartment for each cell. This container is called the battery case. The electrolyte is also placed within this case through a vent, or opening, sealed by a removable plug. Lead-acid storage batteries are frequently supplied without the electrolyte. The electrolyte is added only when the battery is placed in service. This is intended to lengthen the shelf life of the device.

Since the acid is combined with the plates during discharge, the condition of the battery (state of charge) can be measured by measuring the amount of acid in the solution (specific gravity) of the electrolyte. The specific gravity is about 1.260 to 1.280 in a fully charged new battery. Specific gravity of a substance is its comparative weight with respect to the weight of an equal volume of water. The specific gravity of a wet cell is checked using a hydrometer such as the one shown in figure 3-19. The specific gravity of the electrolyte varies with temperature. Figure 3-20 shows the state of charge and specific gravity at 80° F. At temperatures above 80°, it is necessary to add

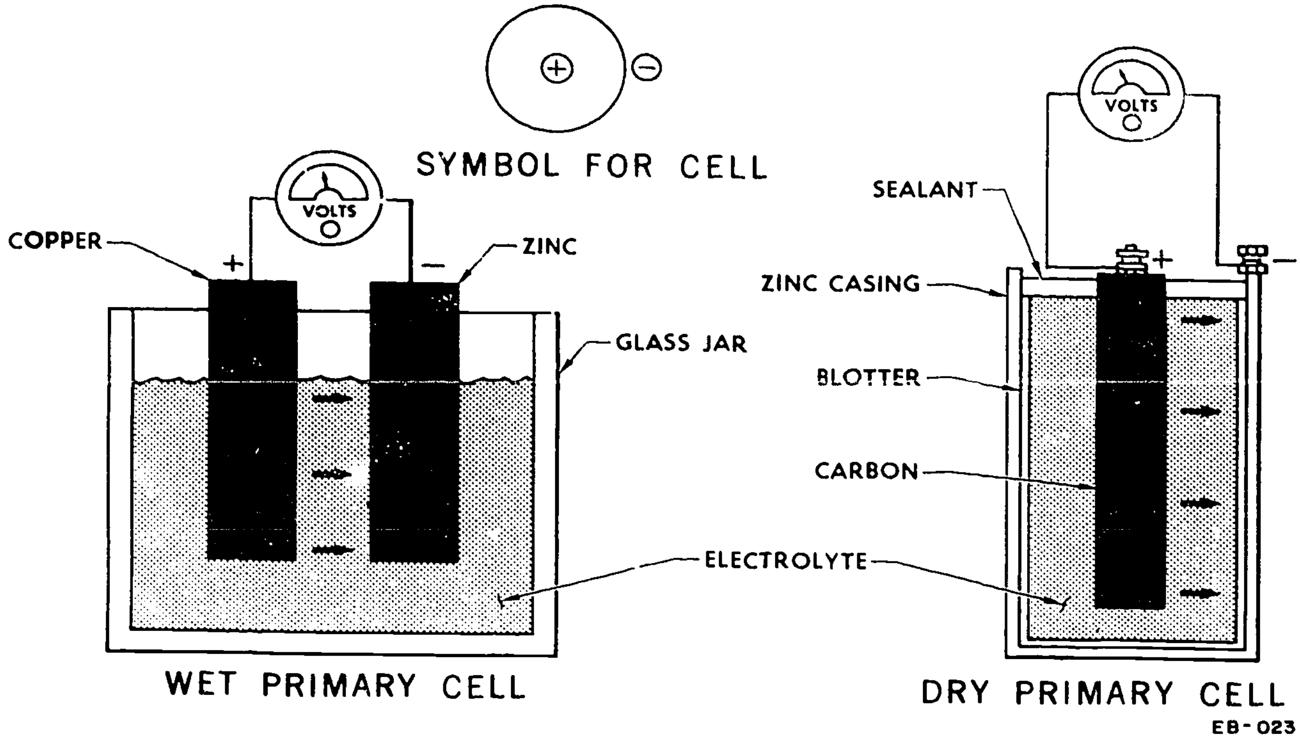


Figure 3-17. Dry cell battery.

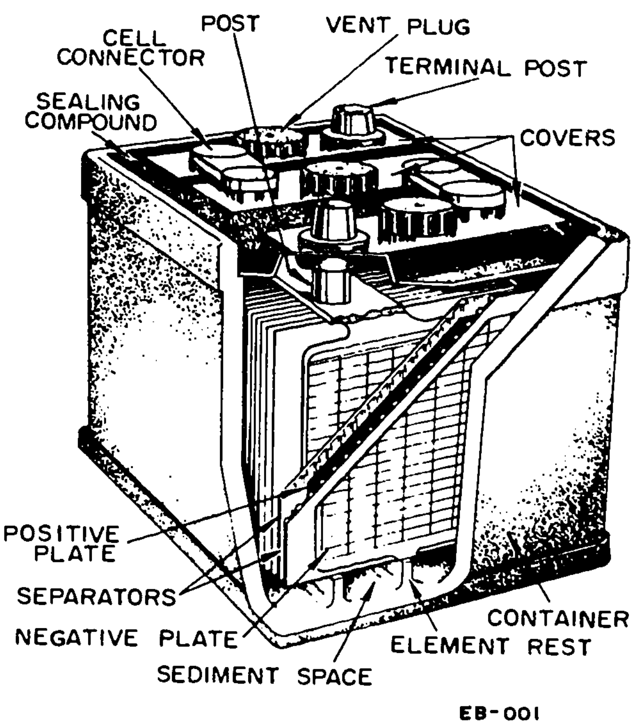


Figure 3-18. Lead-acid battery.

four gravity points for each 10°. Below 80°, four gravity points are subtracted for each 10°. Thus, if the electrolyte is at 110°, the actual reading of 1.235 obtained should be corrected to 1.247 ($4 \times 3 = 12$). If the gravity reading is 1.250 at 0°, a corrected reading would be 1.218 ($4 \times 8 = 32$).

Like that in the primary cell, the action of the lead-acid cell is chemical in nature. When a load is connected through a suitable conductor, the electrolyte is ionized. The sulfuric acid will break down into positively charged hydrogen ions and negatively charged sulfate ions. The hydrogen ions move toward the positive plate and, in combining with the oxygen of the lead peroxide, form water. It is this action that tends to dilute the electrolyte by reducing the acid content and increasing the water, thus reducing its specific gravity.

The positively charged hydrogen ions have, in effect, taken out negatively charged oxygen ions from the lead perioxide plate, leaving the plate positively charged. That i why the lead peroxide plate acts as the positive plate of the battery.

At the same time, some of the sulfate ions join with the lead part of the lead peroxide, forming lead sulfate. Other negatively charged sulfate ions move toward the sponge-lead plate where, combining with positive ions of the lead, they leave the plate negatively charged and form a layer of lead sulfate on its surface. As this takes place, the negative electrons that have accumulated on the negative lead plate are being attracted to the positive plate through the outside conductor. Thus, here again, as in the primary cell, we see

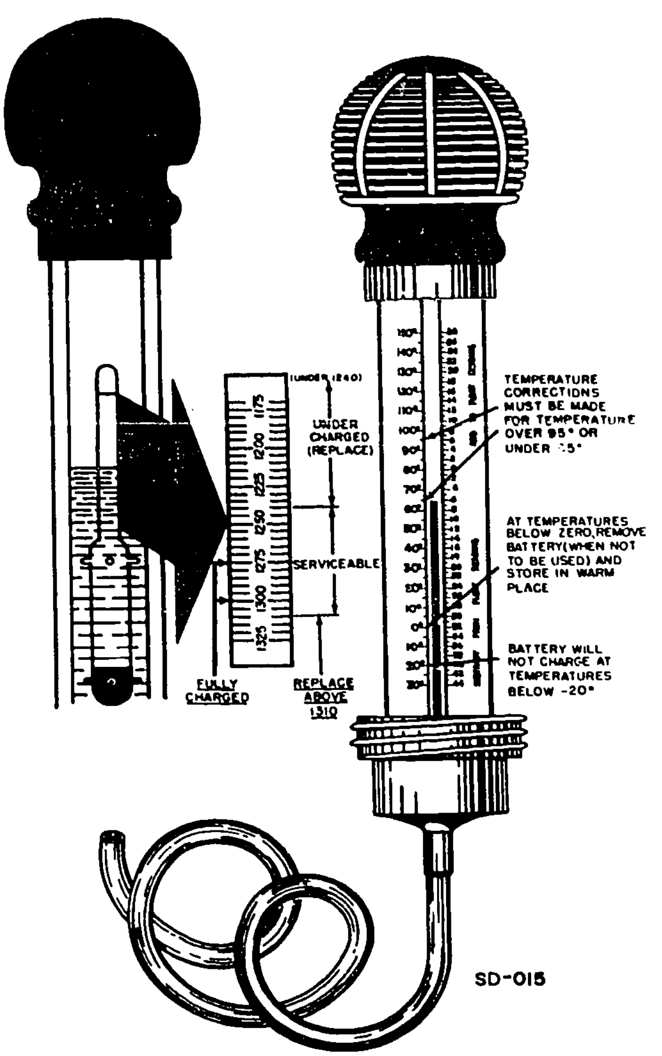


Figure 3–19. Hydrometer.

| SPECIFIC GRAVITY | STATE OF CHARGE |
|---|---|
| 1.260 to 1.280 | FULLY CHARGED |
| 1.225 to 1.250 | 3/4 CHARGED |
| 1.195 to 1.220 | 1/2 CHARGED |
| 1.160 to 1.180 | 1/4 CHARGED |
| 1.130 to 1.155 | BARELY USABLE |
| 1.100 to 1.125 | COMPLETELY DISCHARGED |

E8-052

Figure 3–20. Specific gravity of an electrolyte of 80° F.

an attraction or pressure being set up by the positive electrode, creating a condition that causes the electrons on the negative electrode to move. A fully charged lead-acid battery will usually provide about 2.15 volts per cell at the battery terminal.

*Nickel-cadmium (Nicad) batteries.* The Nicad battery has become another type of battery that is now being used almost as much as lead-acid types. Its cost is probably the only area that deters from buying it.

It is made up of a positive plate made of nickel-wire screen with a nickel powder bonded to it and a negative plate made of the same material but having a metallic cadmium bonded to it. The two plates are placed in a solution of potassium hydroxide and distilled water, which is the electrolyte. The electrolyte does not participate in the chemical reaction of the battery as sulfuric acid does in the lead-acid battery. It simply provides the conductive path between the positive and negative plates. Therefore, the electrolyte's specific gravity does not indicate the state of change of the battery. The specific gravity may range from 1.180 to 1.300. Check with each battery for proper information. A special hydrometer is required. Check manufacturer's information for requirements. The normal open circuit charge of the cell is about 1.30 volts. So remember that there will be more cells in a Nicad battery bank than in a lead-acid bank.

**Exercises (427):**

1. How can a secondary cell be restored?

2. On what does the voltage created from an electrolyte and two different metals depend?

3. The electrolyte of an ordinary dry cell battery consists of what kind of solution?

4. State one item that is powered by a dry cell battery.

5. What are the three most outstanding advantages of a secondary cell over a primary cell?

6. Describe the composition of the plates and electrolyte of a lead-acid battery.

7. What is meant by the specific gravity of a substance?

8. How is the specific gravity of a substance checked?

9. When checking the specific gravity of an electrolyte, when is it necessary to add four gravity points for each 10°?

10. What is the normal open-circuit voltage of a lead-acid battery?

11. Why doesn't the specific gravity of the electorlyte of a nickel-cadmium battery indicate the battery's state of charge?

12. What is the normal open-circuit voltage of a nickel-cadmium battery?

**428. State specific procedures to follow when banking and installing batteries, and give specific details concerning the inspection and maintenance of batteries.**

**Battery Banks.** There are times when batteries must be connected together, as shown in figure 3-21. This is called banking. Banking may become necessary for different situations. For instance, when it is necessary to charge

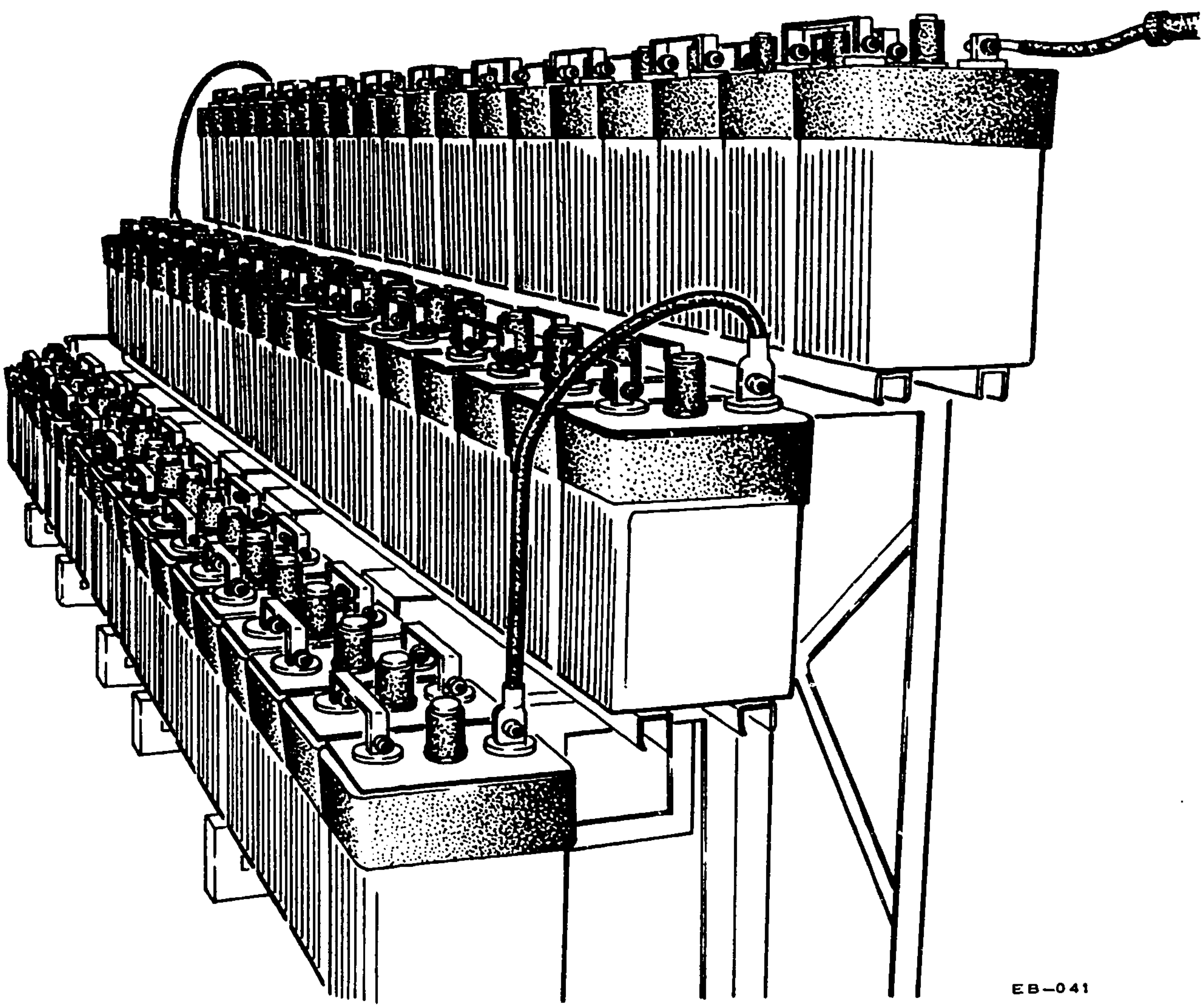


Figure 3–21. Batteries banked in series.

more than one battery at a time, the batteries are usually banked in series. When this happens, the positive post of the first battery is connected to the negative post of the second. This leaves a positive and a negative post to be connected to the charger. If more than two batteries need to be banked in series for charging, they may be connected in the same way. A situation which requires batteries to be banked in series is where more voltage than can be delivered by one battery is required. For example, if a motor crane required a 24-volt battery and none were available, two 12-volt batteries can be banked in series; and the crane can be operated until you obtain the specific battery you need. You can see that the voltage of batteries connected in series is equal to the sum of the voltages of the batteries.

Series is only one way in which batteries may be banked. While they are banked in series for charging or when higher voltage is needed, they may also be banked in parallel. Figure 3-22 shows two 6-volt batteries banked in series and two banked in parallel.

Parallel banking of batteries is used when there is a requirement for more amperage than can be furnished by one battery, but no increase in voltage is desired. A good example of this is the jumper cables that many people use in starting their cars in the winter. By the use of the jumper cables, the batteries of two cars are connected in parallel without having to disconnect the batteries in either car. They must not be connected in series, because the voltages of the two batteries would add and you would damage the electrical units on the car. Remember, to increase voltage, you bank batteries in series, but to increase amperage without increasing voltage, bank the batteries in parallel.

*Battery locations*. Consideration must be given to where battery banks are placed. It is very important to have sufficient diffusion and ventilation of the gases from the battery to prevent the accumulation of an explosive mixture. The live parts of a battery bank could be very dangerous if a conductive path is provided. Because of this danger, battery banks shall be installed in an area accessible only to qualified persons; and the area shall be marked identifying the danger.

*Racks*. If a large number of batteries are installed in an area, you will probably find them mounted on a rack. These racks must be of a rigid frame design and able to support the weight of the batteries. They must also be made of some substance such as metal, fiberglass, or other nonmetallic material and should be able to resist deteriorating action by an electrolyte.

*Trays*. Some battery banks may be installed in trays. These trays are frames, such as crates or shallow boxes usually made of wood or other nonconductive material. These trays must be constructed or treated so as to be resistant to the deteriorating action of the electrolyte.

**Inspection and Maintenance.** Many premature battery failures can be traced to the lack of proper preventive maintenance and inspection. To get good performance from the battery, you must keep it in good working order. These inspections must be performed in accordance with applicable technical orders or the manufacturer's manual.

A storage battery should be kept in a clean condition in a well-ventilated spot. Good ventilation assures proper escape of hydrogen and oxygen gases and prevents overheating of the cells during either charging or discharging.

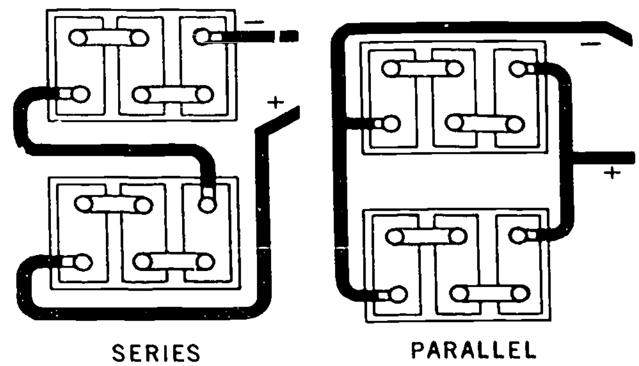


Figure 3–22. Series and parallel battery banking.

CAUTION: A mixture of hydrogen and oxygen is dangerously explosive. Positively no smoking, electric sparks, or open flames are permitted near batteries being charged.

To retard corrosion, use a light layer of petroleum jelly or other grease to cover the terminals. Use a stiff brush (a toothbrush will do) to clean the top of the battery frequently, clearing away dust and corrosive residues that tend to accumulate.

Before connecting the cable clamp onto the battery terminal, thoroughly clean the battery terminal. Then after the clamp is firmly attached to the terminal, apply a light layer of grease to both the clamp and the terminal in order to retard corrosion.

Using a hydrometer, check the specific gravity of each cell and record the results for future reference. (WARNING: Use this hydrometer only on lead-acid batteries. Do not use it on Nicad batteries.)

If a hydrometer used for a lead-acid battery is used on a nickel-cadmium battery, any small amount of sulfuric acid from the hydrometer could, if deposited in the nickel-cadmium battery, destroy its cell. Always wear a protective apron, goggles, and rubber gloves when working with acid.

If required, add distilled water to the cell to obtain the proper electrolyte level. You may use tap water if distilled water is not available. Do not overfill the battery cells (CAUTION: Never allow the electrolyte level to drop below the top of the plates. To do so will damage the battery.)

Proper use and maintenance will assure long life for the battery you are using. Under normal operating conditions, a battery cared for in this matter may last for 5 or more years.

Exercises (428):

1. Name two instances in which batteries are banked in series.

2. What effect will connecting batteries in series have on the total voltage?

3. What effect will connecting batteries in parallel have on the total voltage?

4. Batteries must be installed in an area with plenty of ____________.

5. Of what material must racks be made?

6. Give two ways in which batteries may be installed.

7. What can you use to retard corrosion of battery terminals?

8. What can you use to clean the top of a battery?

9. If distilled water is not available, what can be used to refill a battery cell?

10. What must you wear when working with battery acid?

**429. State the types of battery chargers and give operational details about them.**

**Battery Chargers.** When a lead-acid battery is discharged, it should be recharged. There are two types of chargers which may be used: the motor-generator type and the AC-to-DC rectifier type. The motor-generator is used by telephone exchanges and powerplants in their equipment rooms. The AC-to-DC rectifier is the type used on Air Force installations.

By forcing direct current through the battery in the opposite direction from which the current flows during discharge, the acid is driven back into the water solution, thus restoring the electrical energy as chemical energy. Most chargers have leads marked positive and negative. The one which is marked positive connects to the positive post of the battery, and the one marked negative connects to the negative post of the battery. Thus, you can see that current coming from the charger is higher than that of the battery. During the charging period, a periodic check should be kept on the specific gravity so that the battery can be identified when it has reached full charge.

When a battery is being charged, a portion of the energy is dissipated in the electrolysis of the water in the electrolyte. The water is broken down, and hydrogen is released at the negative plates and oxygen at the positive plates. These gases bubble up through the electrolyte and collect in the air space at the top of the cell. If violent gassing occurs when the battery is first placed on the charger, the charging rate is too high. If the rate is not too high, steady gassing, which develops as the charging proceeds, indicates that the battery is nearing a fully charged condition. Because of this gassing you should keep a close check on the water-acid solution, adding distilled water as necessary. (CAUTION: A mixture of hydrogen and oxygen is dangerously explosive. Positively no smoking, electric sparks, or open flames are permitted near batteries being charged.)

**Rectifiers.** In order for any battery charger to function, you must have an electrical device that will change AC into some form of DC. A rectifier is used to change AC to DC. The DC that comes from the rectifier will be full-wave or half-wave pulsating current, as shown in figure 3-23.

Certain equipment, such as relay coils, battery chargers, and electronic equipment, operates on DC. For these reasons, rectifiers were developed and used.

*Theory.* As we already know, AC changes direction each alternation (or every 180 electrical degrees), and there are two such alternations during each AC cycle (or every 360 electrical degrees). We also know that DC flows in one continuous direction. Before AC (produced by the generator) can be used in DC circuits, it must be changed to have the same characteristics as that of DC. This is where the rectifier comes into the picture. When a rectifier is wired into a circuit, it changes the AC input into DC output required by the load(s).

Rectifiers, in general, can be broken down and classified into several groups; however, here we need only to concern ourselves with two. They are the dry-disc and crystal rectifiers.

*Dry-disc rectifiers.* One of the earlier types of rectifiers developed was the dry-disc rectifier. The operation of this type of rectifier is limited to the amount of current, voltage, and heat that it can withstand. For these reasons, dry-disc rectifiers are being used less as improved systems of rectifiers are being developed. Most dry-disc rectifiers are of the selenium-iron type, which is made up of a prepared

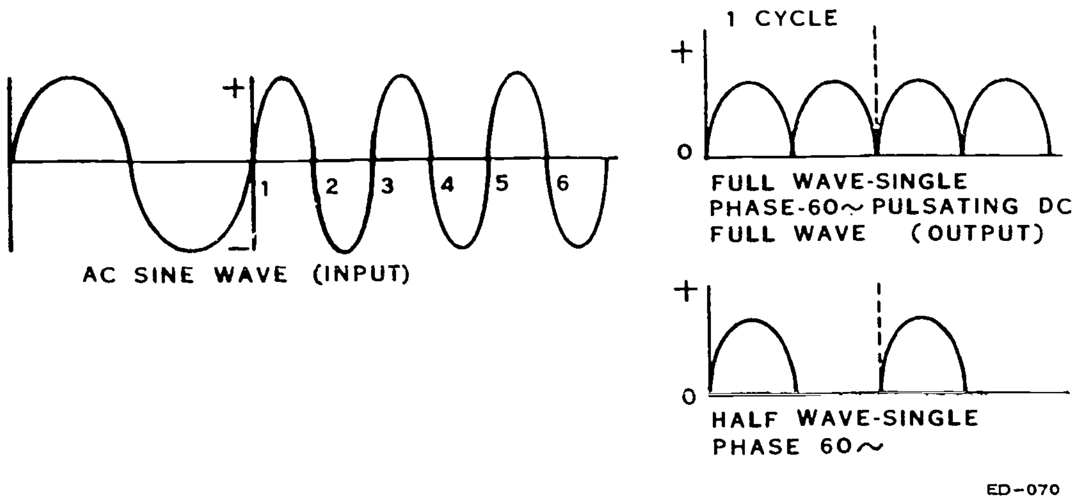


Figure 3–23. Waveforms.

film of selenium on a metallic substance such as iron. See figure 3-24.

In actual operation, the combination of iron, selenium, and conductors offers a *low* resistance to current flow from iron to the selenium, but offers a *high* resistance to current flow from selenium to the iron. Take, for an example, an AC cycle. The current in this case would be allowed to flow freely in only one direction, from selenium to iron. As the current changes direction (second alternation), its path to the load would be blocked by the junction.

A full-wave, dry-disc rectifier has four terminals. Two terminals are for AC input. It does not matter which AC lead is connected to the AC terminals because the current will periodically reverse. You should identify the DC terminals in order to maintain the proper polarity to the unit. A DC voltmeter can be used for this purpose. In practice, a number of discs may be placed together in series or parallel to form a rectifier assembly. Metal plates, much larger than the discs, are usually assembled between each disc section to aid in cooling. To increase the *voltage output* capacity of a rectifier, a number of discs are connected in series. To increase the *ampere capacity* of a rectifier, a number of discs are connected in parallel. A series-parallel combination increases both the *voltage* and *ampere* capacity of the rectifier. See figure 3-25.

*Crystal recitifers*. A smaller, cheaper, and more efficient substitute was needed for the vacuum tube and dry-disc rectifier in recent years. After a lot of research, it was determined that one could grow a crystal substance to which impurities could be added to form a semiconductor. Germanium is a good example of a type of crystal used.

Like the dry-disc plate, we can join a negative semiconductor to a positive semiconductor and create what we call a diode, which is a device that will pass current easily in one direction and block current in the other direction. Figure 3-26 shows a diode and the direction of its current flow.

*Half-wave rectifiers*. The simplest type of connection for rectifiers is known as the *half-wave* circuit. These circuits are normally found in AC voltmeters. In a half-wave circuit, current flows in the desired direction during only one-half an AC cycle; hence the name "half wave". During the other half cycle (second alternation), current is blocked. In figure 3-27, the output of a half-wave rectifier is shown by using sine waves. Figure 3-28 shows a diode in a half-wave rectifier circuit. As you have seen, a half-wave rectifier will block the second half of an ac cycle, and a series of pulses will result. Hence, the frequency of a rectifier is measured in pulses per second (PPS). In a *half-wave* circuit, the number of pulses is equal to the applied frequency. For example, a 60-cycle frequency will produce 60 pulses.

*Full-wave (bridge type) rectifiers*. A more common type of rectifier circuit is the *full wave* (bridge type). The output of a full-wave (bridge type) rectifier is shown by using the sine wave in figure 3-29. Unlike the half-wave rectifier, the full-wave makes use of the second half of the ac cycle in that the second half reaches the DC load from the same direction as the first half. In other words, the second alternation has been changed (modified) to follow the same path as the first alternation.

As you know, the frequency for a rectifier is measured in pulses per second. In a half-wave rectifier, the number of these pulses is equal to the applied frequency. But in full-wave rectification, the number of pulses per second is equal to *twice* the frequency. Thus, for a 60-cycle current using full rectification, there are 120 pulses per second.

The bridge type rectifier has four diodes or four or more selenium plates connected together to create the sine wave previously discussed. The symbol for a full-wave (bridge type) rectifier is shown in figure 3-30. The polarity of a full-wave rectifier circuit may be determined by the direction of arrows; that is, the arrows will point towards the positive side of the rectifier. Notice in figure 3-30 that

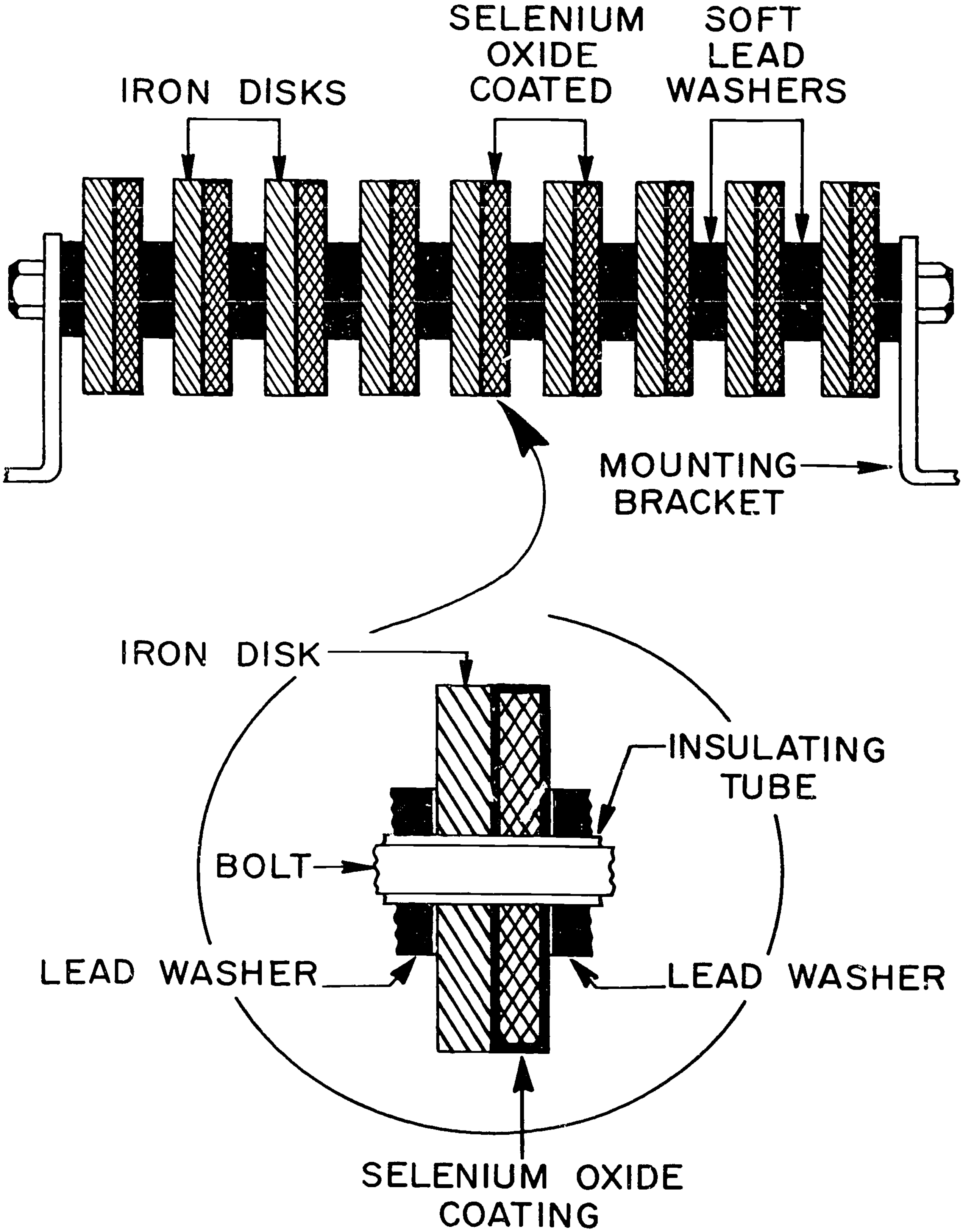


Figure 3-24. Dry-disc rectifier.

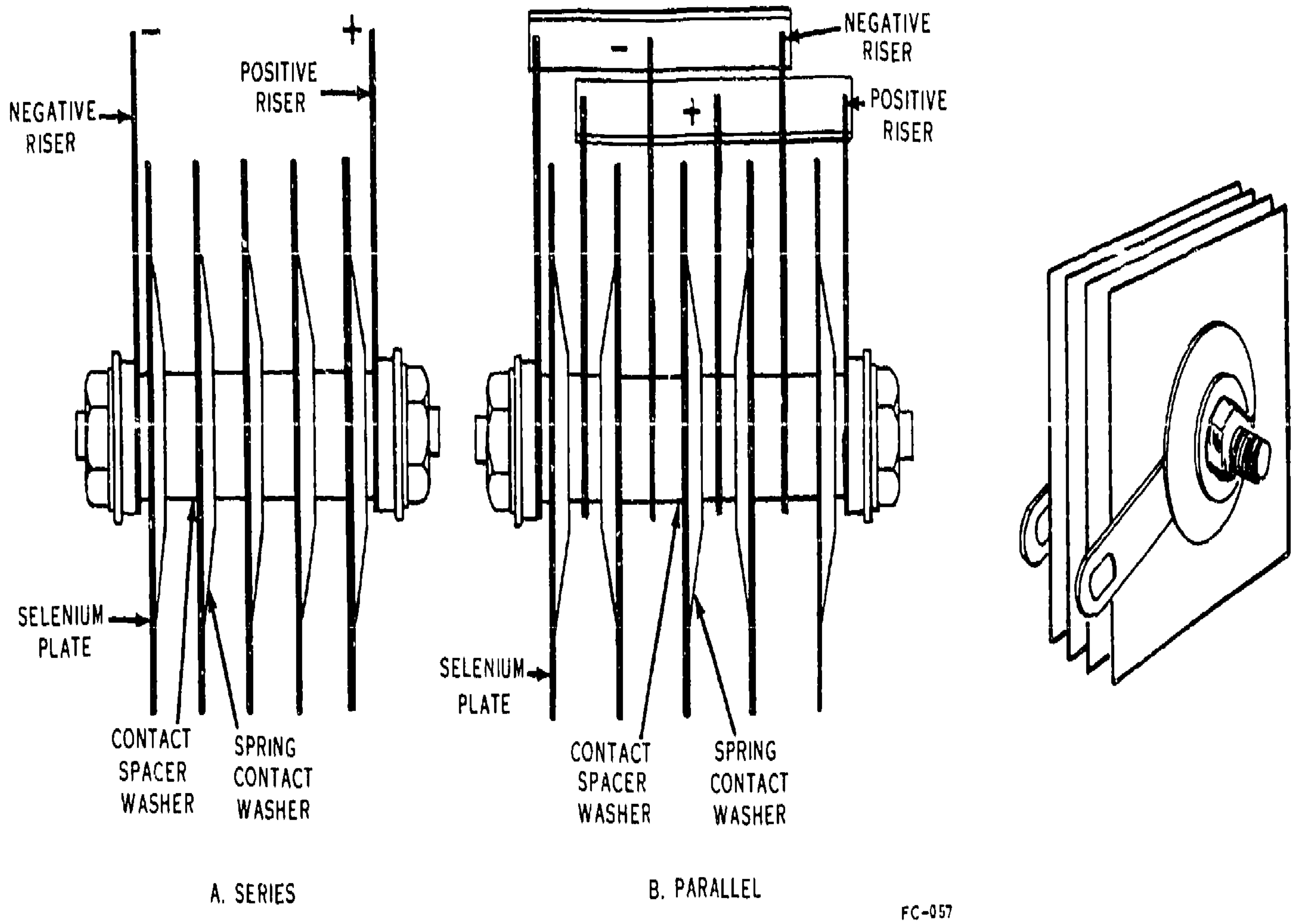


Figure 3-25. Rectifier plate and stack for series and parallel connections.

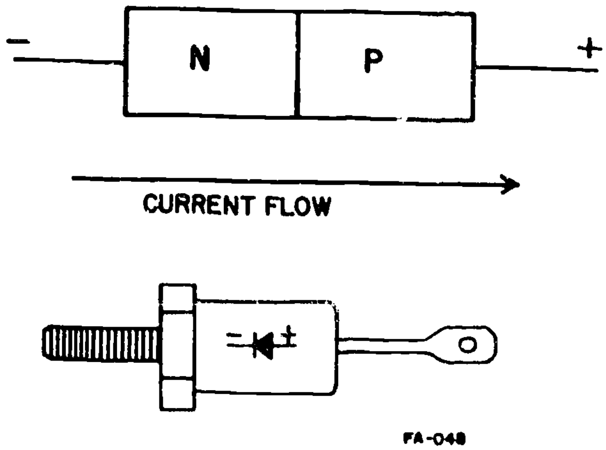


Figure 3–26. Diode action.

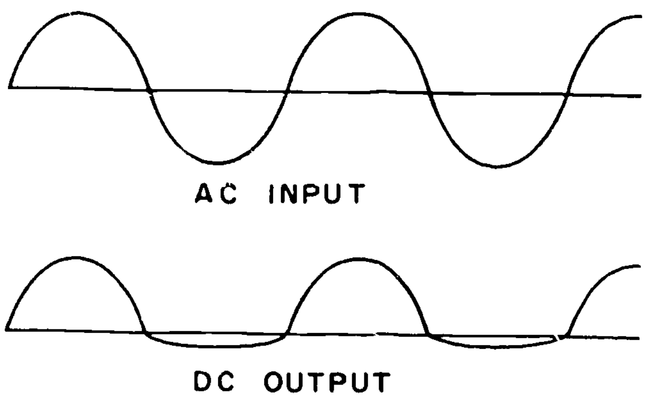


Figure 3–27. The output of a half-wave rectifier.

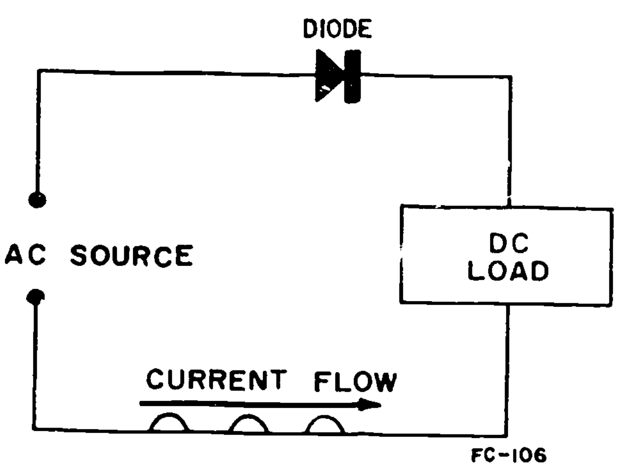


Figure 3–28. Half-wave rectifier circuit.

all arrows point towards positive. Once you have determined which side is positive, the opposite side would be negative.

Figure 3-31 shows how this symbol is used in a full-wave (bridge type) rectifier circuit. Some rectifiers may contain a filter in the DC output which is used to increase conversion efficiency and/or reduce interference. In most cases, this will be what is referred to as a "single L-section filter." This will be made up of a choke connected in series with one of the DC leads and capacitors connected between the positive and negative terminals on the output of the rectifier. See figure 3-32 for a typical circuit of a filter.

**Exercises (429):**

1. Name two types of battery chargers.

2. State what happens in the actual process of charging a lead acid battery with an AC-to-DC rectifier.

3. Why does gasing occur during charging?

4. What is the purpose of the rectifier in a battery charger?

5. Why is it dangerous to smoke around a battery being charged?

6. Of what materials are most dry-disc rectifiers made?

7. What limitations does a dry-disc rectifier have?

8. Name two advantages of a crystal rectifier.

9. How does current flow in the first and second half of an AC cycle in a half-wave rectifier?

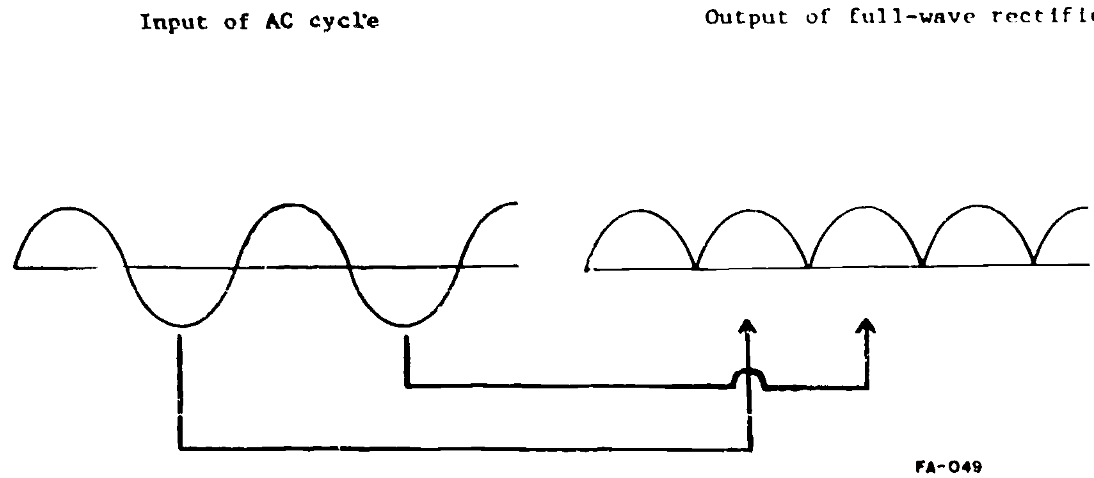


Figure 3–29. The output of a full-wave rectifier.

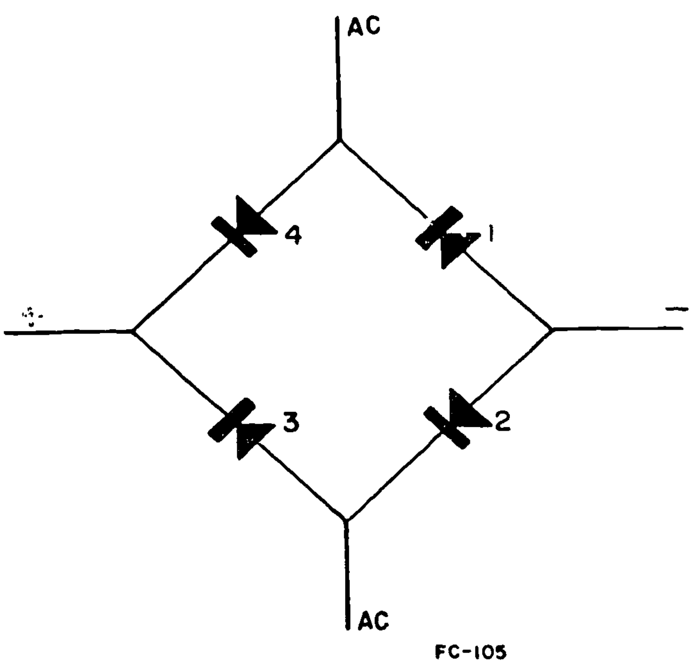


Figure 3–30. Full-wave (bridge type) rectifier.

10. A full-wave dry-disc rectifier will have how many terminals?

11. A full-wave bridge type rectifier has how many diodes?

12. State the parts of a single L-section filter.

**430. Specify installation, inspection, maintenance and troubleshooting procedures for battery chargers.**

**Installation and Connection Procedures.** Battery charging equipment must be installed and connected in accordance with the manufacturer's specifications. There are no real requirements in the National Electrical Code, except for branch circuit situations.

**Inspection and Maintenance Procedures.** Again, like the installation aspect, the inspection and maintenance of a battery charger is primarily dependent upon the manufacturer's requirements. One can insure proper operation by keeping the unit clean and allowing plenty of ventilation. Two problems that affect a lot of electrical equipment is tinkering and pilferage. These problems can be reduced by locking cabinets or securing the area where the battery charger is located.

**Troubleshooting and Repairing/Replacing Procedures.** A battery charger has two principal components; the transformer and the rectifier. Like the majority of electrical equipment, it either works or does not

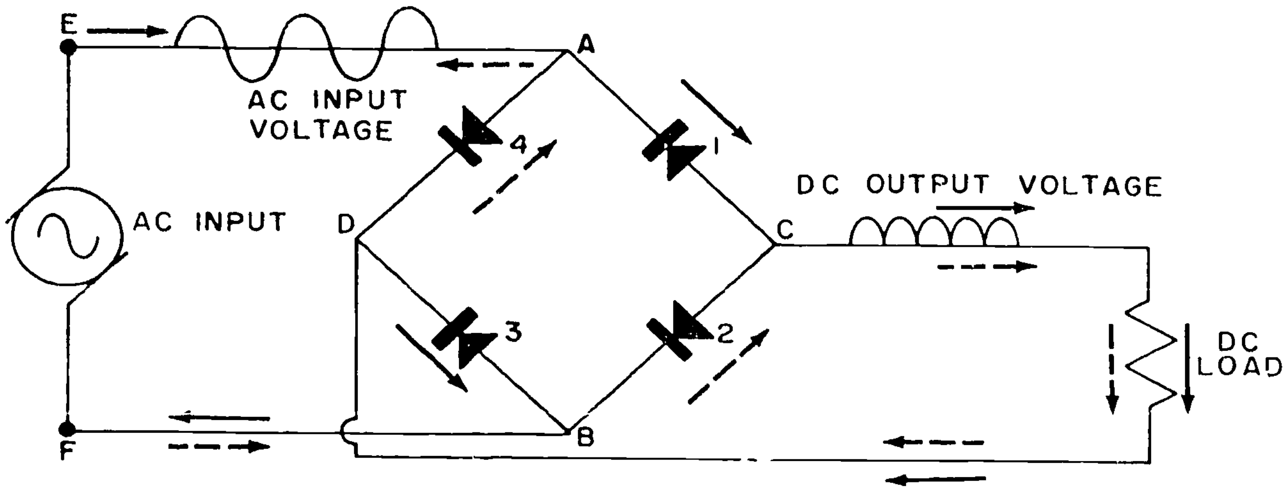


Figure 3–31. Full-wave rectifier circuit.

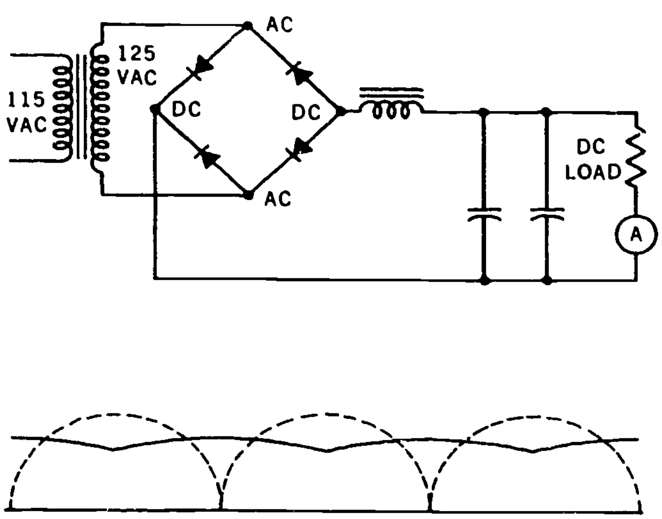


Figure 3–32. Rectifier filter circuit.

work. Rectifiers are included in that statement. If a rectifier passes current and the proper pulsating DC is obtained, the system is OK. The waveform of the rectifier can be checked with an oscilloscope. If there is a voltage input and no voltage output, the rectifier is bad and must be replaced. The disc in a dry-disc rectifier can be felt for proper temperature operation. A disc that is too hot reflects too much current flowing through the disc and damage will result. Again, the manufacturer's specifications will sometimes give trouble-shooting techniques and should be followed.

**Exercises (430):**

1. State important maintenance items that must be followed to insure proper operation of a battery charger.

2. If you have voltage input to a rectifier but no output, what would you do?

3. What instrument would you use to check the wave form of a bridge rectifier for proper output?

4. How would you check a dry-disc rectifier for proper temperature?

**431. Restate common problems and procedures for troubleshooting batteries and battery banks.**

**Troubleshooting and Repairing/Replacing Procedures.** During some of the maintenance steps that you perform, you may find a battery or battery bank that indicates a trouble. Some possible troubles that may occur are:

*a*. Shorted cell.
*b*. Open cell.

*c*. Low specific gravity that won't increase during a charge.

*d*. Dead cell, no voltage present.

To locate the troubles mentioned above, several devices may be required. If a battery is suspected, a hydrometer check will be your first test. This will tell you what cells, for whatever reason, are not charging properly. Once the cells are identified, a voltmeter will indicate, by a low or no voltage reading, an open or shorted cell.

If neither a hydrometer reading or a voltmeter reading confirms the exact problem, then it may be necessary to take an ammeter-load check. In this check a resistive load with an ammeter installed is placed across the terminals of the battery. This device will show, in amperes, how much current the battery can provide. A weak or sulphated cell that will show a good charge and a full voltage will not be able to sustain that voltage under load.

In any case, if one of the troubles just mentioned occurs, the electrician must replace the battery. Replace it by disconnecting the battery terminals, making sure which are the positive (+) and negative (−) leads. Using the proper device, lift the battery out of its box or rack and place it on the floor or a table. It should be disposed of in accordance with prescribed directives. Clean the battery box or rack area properly before you install the replacement battery.

Make sure the new battery is completely serviced. If the battery has the electrolyte already in the battery, all you have to do is insure that the battery has a proper charge. If your new battery comes in a dry state, you will have to fill each cell with an electrolyte of the prescribed specific gravity. The electrolyte is usually supplied by the battery manufacturer, and when available, it should be used. If it is not available, you can mix the electrolyte solution, using sulfuric acid and distilled water.

WARNING: Always pour acid into water. Never pour water into acid, as this will cause a violent chemical reaction that will splatter the solution over the surrounding area. Pour the acid very slowly into the water while slowly stirring the solution. Do not hurry! You must wear goggles, a rubber apron, and rubber gloves for your protection during this procedure.

After being properly serviced, lift the new battery and place it in the box or on the rack in the same location as the old one. After applying a small amount of grease to the terminals, connect the leads.

CAUTION: Where one of the terminals connects to ground, always connect the ungrounded terminal first. This prevents sparking if your wrench touches the ground or frame while you are tightening the terminal.

**Exercises (431):**

1. Name four possible troubles that may occur with a battery.

2. When one or more of the troubles mentioned in question 1 has been identified, what may it be necessary to do?

3. Bad batteries must be disposed of in what manner?

4. After the electrician has removed the defective battery and cleaned the rack, the new battery must be installed. Which terminal should he connect first and why?

## 3-4. Emergency Lighting

How many times have you seen a funny-looking box mounted on the wall with two lights attached to the top? In fact, if you are very tall, you might have had to duck or tilt your head to keep from hitting the boxes. These boxes are called emergency lights and are a very important part of a building's electrical system. The exit light is also an important identifier within a building.

**432. Give the types, construction features, and operation of emergency and exit lights.**

**Purpose of Emergency Lights.** An emergency light is a very important electrical device. It is used to provide a temporary source of light in case the regular lighting system fails. The regular lighting system could fail due to fire, storms, equipment failure or loss of commercial power. When one of these problems develops, the emergency light senses the loss of AC power and automatically turns on the DC lights mounted on the cabinet. The lights receive their power from a storage battery within the cabinet. When AC power is restored to the emergency light, the DC lights are automatically turned off.

Emergency lights are used in department stores, industrial plants, theaters, hospitals, barracks, dining halls, and office buildings. They are very important in preventing panic and thefts, saving lives, assuring orderly evacuation, and preventing work stoppage during blackouts.

**Construction Features.** The typical emergency light will contain a rechargeable battery; battery charger; low-voltage incandescent floodlights; and test, monitoring, and control accessories.

*Rechargeable battery*. Most emergency lights have some sort of battery, either a lead-acid type or a nickel-cadmium type. These batteries must be built to have a longer, trouble-free life on trickle charge. Most of these batteries also have a specific gravity indicator on the front of the battery. Follow the manufacturer's data about your specific battery to insure proper operation.

Most emergency-light batteries are of the 6-volt type. In a few cases, there are some 12-volt types that are used, but

they are not as common. Figure 3-33 shows one type of emergency light battery, the sealed lead-acid type.

*Battery charger*. The battery charger of an emergency light has a solid state charger. The detector and regulator are used to provide a continuous, infinitely variable current-limited charge rate as demanded by the battery to maintain it fully charged at all times. The solid-state charger will vary in size, but with the common 10.25-ampere current-limited transformer, it can recharge the accompanying battery within 12 hours to rated voltage after discharge to 91 percent nominal with rated load. One type of battery charger is shown in figure 3-34.

*Low-voltage incandescent floodlights*. Most emergency lighting systems use a 25-watt, 6-volt sealed-beam lamp. This lamp has a light pattern that is relatively wide in the vertical plane. This means that it will be most effective when illuminating a large open area, such as a rectangular store or work area. A good rule of thumb is that one incandescent lamp will be sufficient for approximately 1000 square feet if the lamp is located so that its full light pattern can be utilized. These lights can be mounted on the unit proper or in a remote location. See figure 3-35.

*Accessories*. The test monitoring and control accessories of emergency lights will consist of a test button used to test the operation of the relay and switching network. A pilot light lets you know that the unit has AC power applied. An ammeter tells you the amount of charge the battery is requiring and receiving. In some cases, there will be a ready light to let you know the system is ready for operation and a relay which does the changeover when AC power is lost.

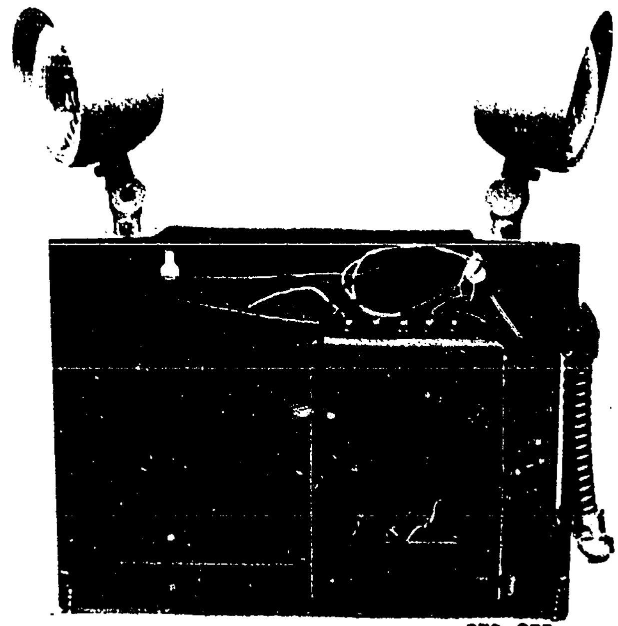

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Figure 3–34. Battery charger.

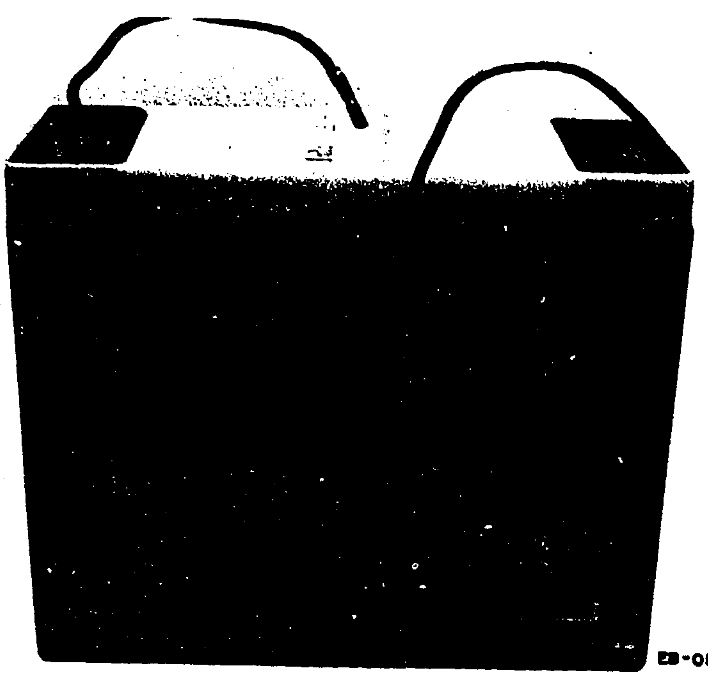

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Figure 3–33. Sealed lead-acid battery.

Although we have concentrated our subject so far on the incandescent types of emergency lights, there is also a fluorescent emergency lighting system. This fluorescent system uses a battery in conjunction with a ballast for operation. It must be connected in a branch circuit that is not switched and must remain on at all times. Figure 3-36 shows a ballast, battery, and test switch used for a fluorescent emergency light.

**Application and Theory of Operation.** Emergency lighting systems are used in the Air Force to a great extent. You can find them in every building where people work. In fact, if you were to check, you could probably find an emergency light everywhere except in the housing units.

The emergency lights, whether incandescent or fluorescent, have an important mission. These systems are sensing AC at all times through a line-voltage relay. If the AC power to these lights is lost, for whatever reason, the relay will deenergize and close a set of contacts and turn on the lights. Once AC power is restored, the line-voltage relay will energize and open the contacts and turn off the lights. Figure 3-37 shows a wiring diagram of a fluorescent emergency light. Figure 3-38 shows a wiring diagram of an incandescent emergency light.

**Exit Lights.** Another type of emergency light that is used is the exit light. Its main purpose is to provide a means of identifying the outside doors to a building.

These lights have either an incandescent or fluorescent system and a transparent glass with EXIT painted on one or both sides of the fixture. The National Electrical Code and AFM 88–15, *Air Force Design Manual—Criteria and Standards for Air Force Construction*, require that these lights be connected ahead of the main entrance switch. This

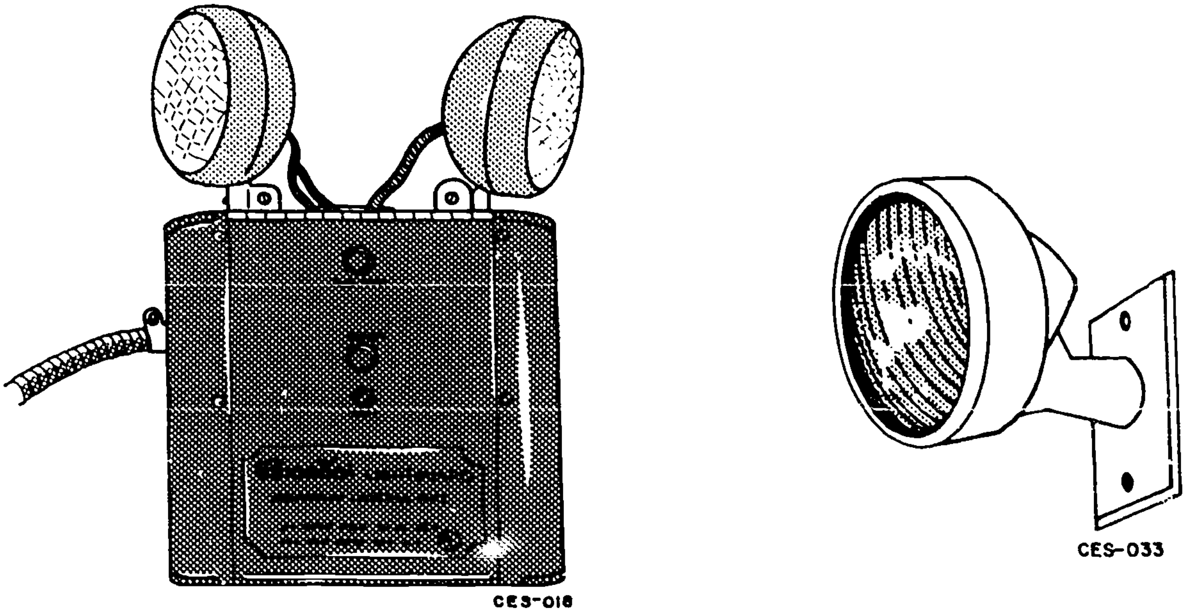


Figure 3–35. Low-voltage incandescent floodlights.

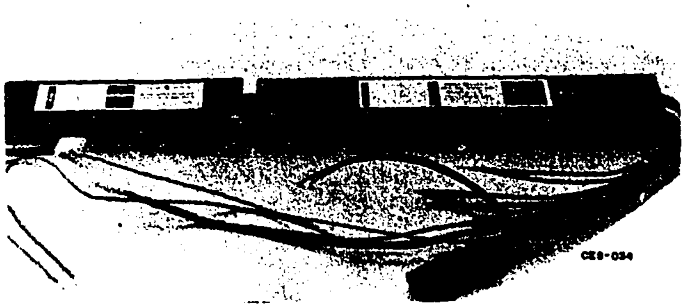

Figure 3–36. Accessories of a fluorescent emergency light.

allows the power to be shut off and the exit lights to still work.

**Exercises (432):**

1. When do emergency lights operate?

2. Name the four parts of the emergency light.

3. Most emergency lights use a ____________-volt battery.

4. In most cases, the battery in an emergency light can be recharged within ____________ hours.

5. The incandescent lamp on top of emergency lights are of what type?

6. Each lamp of an emergency light will sufficiently cover ____________ square feet.

7. What happens when the AC power is lost to an emergency light?

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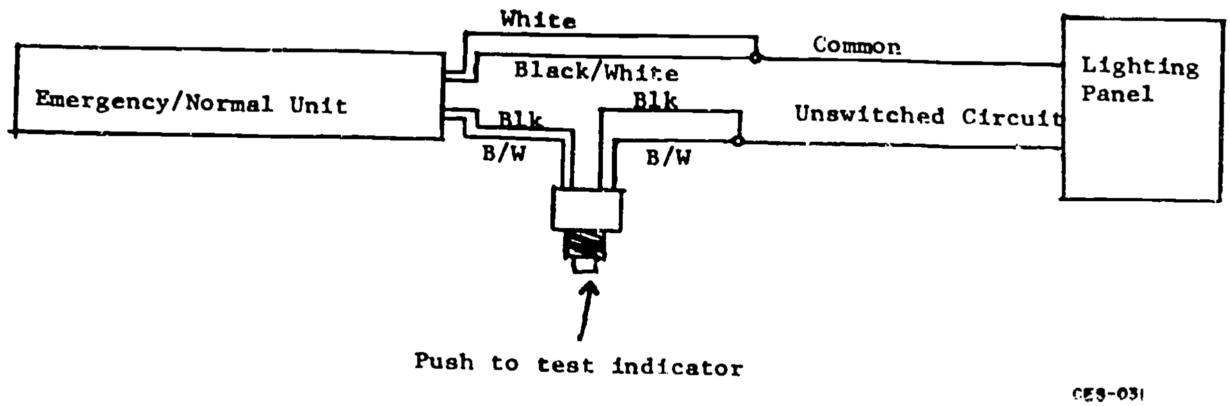


Figure 3–37. Fluorescent emergency light schematic.

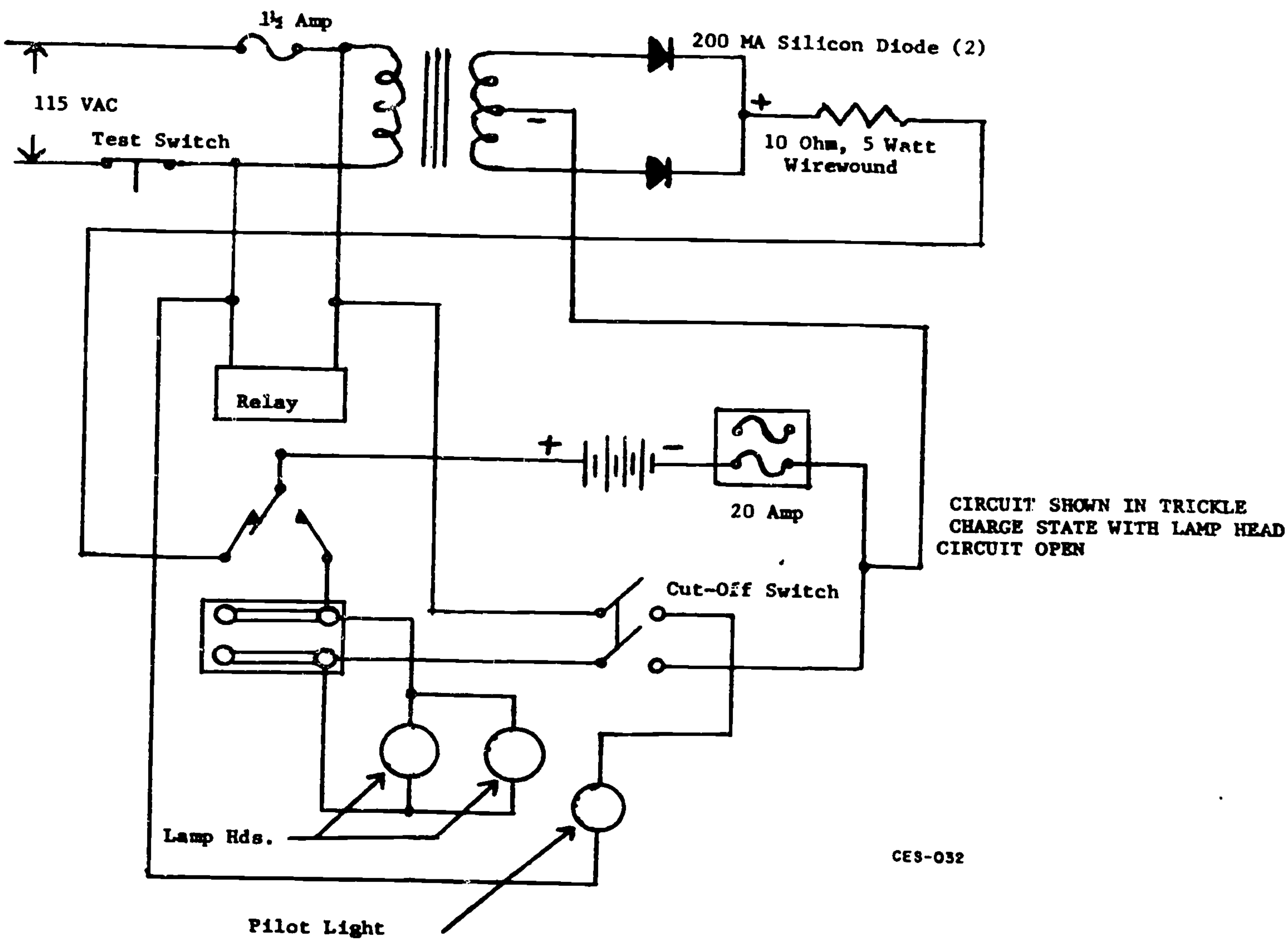


Figure 3–38. Incandescent emergency light schematic.



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8. Why are exit lights required to be connected ahead of the main entrance switch?

9. What purpose do exit lights serve?

10. On which type(s) of systems do exit lights operate?

**433. Explain specific details of installation and connection procedures for emergency lights.**

**Installation and Connecting Procedures.** Emergency lighting systems are installed and connected so that they will come on when commercial power fails. The things you must consider for proper operation are the source of power, circuitry, illumination, and wiring.

*Sources of power.* The power supply to an emergency light must be such that in event of failure of the normal supply to or within the building, emergency lighting will operate immediately. The emergency power supplying the emergency light, whether in the light or in a battery bank, must be capable of maintaining at least 87½ percent of the system voltage for a period of at least 1½ hours. Batteries, whether of the acid or alkali type, shall be designed and constructed to meet the requirements of emergency service, and must be compatible with the charger for that particular installation. The containers of lead acid batteries, which require water additions, must be of a transparent or translucent material. Maintenance-free batteries don't require a transparent container, and automotive-type batteries are not used in emergency systems.

*Emergency lighting circuit.* No appliances and no lamps, other than those specified for emergency use, shall be supplied by emergency lighting circuits. This means that the branch circuit supplying exit and emergency lights shall be free of all electrical equipment except the emergency lights themselves. It is further against the code to add any emergency lights to a branch circuit that already contains appliances or other electrical equipment.

*Emergency illumination.* Emergency lighting systems must be so installed that the failure of any individual lighting element, such as the burning out of a light bulb, will not leave any space in total darkness.

*Independent wiring.* The wiring for emergency systems must be kept entirely independent of the regular wiring used for lighting. Therefore, it needs to be in separate raceways, cables, and boxes. This requirement is to insure that where faults occur on the regular wiring, they will not affect the emergency system wiring, as it will be in a separate inclosure. The branch-circuit fuse or circuit breaker in these emergency circuits is accessible to authorized persons only.

**Exercises (433):**

1. If AC power fails, what is the requirement of the emergency power supply?

2. Lead-acid batteries of the water addition type must have what type of container?

3. Circuits for emergency lights must be installed in what manner?

4. If one bulb of an emergency light burns out, what requirement must be met?

**434. Explain specific details about the inspection and maintenance of emergency lights and the problems and procedures for troubleshooting them.**

**Inspection and Maintenance Procedures.** Emergency lighting systems require maintenance. If they are checked for proper operation, they can last a long time and provide the user an effective piece of equipment. Again, the manufacturer's data and National Electrical Code provide some good ideas.

The authority having jurisdiction, which is usually the electrical inspection section, must conduct or witness a test on the emergency lighting system upon installation. After this initial test, these systems must be tested periodically on a schedule acceptable to the civil engineering personnel. This testing helps to assure that emergency lights are in proper operation. A written record must be kept of all tests and maintenance that are performed. This provides information and a history of how the system has performed.

The primary maintenance concern of an emergency lighting system is to make sure the batteries are properly taken care of. Lead-acid batteries that must have water added must be inspected on a monthly basis for the following:

*a.* Check electrolyte level and add distilled water if needed.

*b.* Check charging rate. Adjust charging rate as necessary to maintain proper specific gravity.

*c.* Test for proper operation under simulated power interruption.

*d.* Replace lamps as necessary.

*e.* Wash battery terminals with a solution of baking soda and warm water to remove any film or corrosion that may be present. Then apply a small coat of lubricant.

If the emergency system uses maintenance free batteries, they must be checked on an annual basis.

About every 6 months, discharge the battery until the hydrometer on the case shows discharged. The simplest way to do this is to remove the 110-volt fuse or turn off the overcurrent device. After discharge, replace the fuse or turn on the overcurrent device and allow the battery to charge. This procedure will break up deposits that form on the battery plates due to the trickle charge and will prolong the life of the battery.

**Troubleshooting, Repair and Replacement Procedures.** Emergency lighting systems are pretty much trouble-free. If one were to concentrate on a weak area, it would have to be the battery and charging circuit.

If the battery won't hold a charge or the specific gravity will never come up to specific requirements, it needs to be replaced. Make sure the battery is replaced with the same type, voltage, and current capabilities. If other problems exist, refer to the troubleshooting procedures discussed in the section on batteries and battery banks.

If the charging system does not put out a voltage, look for a bad fuse, transformer, diode or bridge rectifier (wound resistor).

The transfer relay will give you trouble once in a while. If it does stop operating, it is usually the plug-in type, and a new one can be inserted in the old one's place.

**Exercises (434):**

1. How often should lead-acid batteries of the water-addition type be tested?

2. Who establishes the monthly schedule for maintenance of an emergency system?

3. What type of record must be kept on the test and maintenance of an emergency lighting system?

4. When inspecting an emergency light, what is your primary concern?

5. If, when inspecting a battery, you discover corroded battery terminals, what maintenance steps would you perform?

6. How often should the battery in an emergency light be completely discharged and then recharged?

7. What should you do if the battery in an emergency light will not hold a charge?

8. A transfer relay is usually of what type? What should you do if the relay stops operating?

9. If the charging system in the emergency light does not have a voltage output, what three items might be causing the problem?

## 3-5. Dining Hall and Domestic Appliances

This text covers the electric heating and cooking equipment ordinarily used in domestic quarters, hospitals, and dining halls on Air Force installations. Although the types of equipment used may vary, the basic operational parts of these appliances, such as the heating elements, switches, motors, and thermostats are the same. There are three basic types of kitchen equipment: element heated, motor driven, and a combination of both motor driven and element heated.

### 435. Explain the operation and state the types of appliance controls.

Appliance controls, as the name implies, turn off and on and regulate the electric appliances we use daily. There are two general classes of controls: manual and automatic. Manual controls turn the appliance off and on, and some types set the appliance at a desired temperature by controlling the current flow to the unit. The automatic control in addition to turning the unit off and on, maintains an even heat in the unit. The even temperature of automatic controls results in better food preparation and allows more time for the food preparer to accomplish other essential tasks.

**Manual Controls.** Manual controls turn the heating unit off and on by making or breaking the electric circuit. Manual controls consist of the toggle switch and different types of rotary switches.

*Toggle switch.* This type of control is used to make and break the electric circuit on many small appliances. They are normally installed in the appliance cord or in an electrical box. Repair on this type of switch is limited to replacement. New switches are usually so inexpensive that repairing an old one is not economical.

*Rotary switch.* Rotary switches have fast make-and-break action and usually have three or more heat settings. The fast make-and-break contacts help eliminate the usual pitting and burning of the contacts. Contacts can move fast by spring action within the switch.

Rotary switches are normally used to control the top elements of an electric range. Changing the position of the switch changes the voltage and connection to the element. For example, the LOW position connects the elements in series to a 120-volt power source, while the HIGH position connects the elements in parallel to a 240-volt power source. Various combinations of these connections deliver different heat from the unit, all controlled by the rotary switch. Figure 3-39 shows a typical rotary switch.

Repair of this switch is recommended only as a temporary measure. Repair consists of cleaning and adjusting contacts, replacing worn and inoperative parts, and lubricating contacts and the switch mechanism with nonoxide grease for smoother operation. The switch should be replaced as soon as a replacement is available.

*Pull-and-turn switch*. The pull-and-turn switch, shown in figure 3-40, is constructed to carry the higher loads connected with commercial ranges and oven installations in dining halls and the like. The current is interrupted ahead of the make-and-break of the switch contacts. This eliminates the usual pitting and burning of contacts. This switch cannot be repaired. You must replace it.

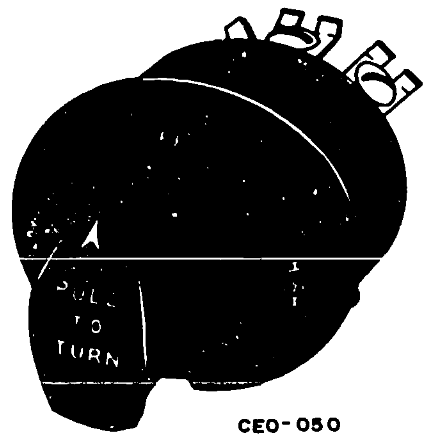


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Figure 3–40. Pull-and-turn switch.

**Automatic Controls.** The basic function of the automatic control is turning current off and on as required to maintain a desired temperature.

*Bimetallic blade*. The bimetallic blade control, as shown in figure 3-41, is operated by the expanding and contracting effect caused by heating two pieces of dissimilar metals that are welded together. Repair of this control is limited to an adjustment in its temperature setting.

*Helix control*. The helix control (the parts of which are shown in fig. 3-42) is used in some domestic, semicommercial, and commercial installations. It is operated by a thermostatic metal that coils and uncoils when heat is applied, operating a switch to make and break the electric circuit. Repairing this unit consists of replacing miscellaneous parts such as the switch assembly, helix, helix guard, dials, and so on.

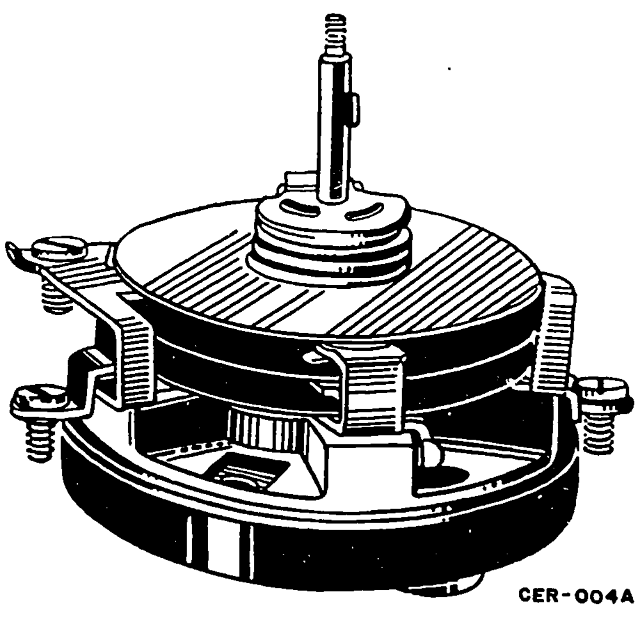

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Figure 3–39. Rotary switch.

*Hydraulic control*. The hydraulic control is probably the most frequently used control for automatically regulating the temperature of cooking appliances. It uses a capillary tube, filled with fluid, connected to a hydraulic bellows. See figure 3-43. The capillary tube has a bulb on one end, which is filled with fluid. The bulb is put in the heat zone and transfers heat-created pressure through the capillary to the diaphragm. The expanding diaphragm presses a system of levers which snap the electrical contacts open, thus cutting off electrical current to the controls. Automatic recycling takes place with slight temperature drops, maintaining a constant set temperature.

Certain types of hydraulic controls have a safety device, set normally at 450° F., to trip and shut the unit off. This safety device must then be manually reset. It may take several hours before the appliance has cooled down enough to allow the operator to reset the unit.

Repairing the hydraulic control is usually limited to adjusting the temperature setting to correspond with the temperature recorded in the appliance. You can adjust the temperature control by loosening, but not removing, the two small, slotted lock screws (fig. 3-43) that are hidden behind the dial. Now, with one hand, hold the main center hub of the control and move the slotted adjusting plate to the right to raise the temperature, or to the left to lower the temperature. This is a delicate adjustment, so move the dial a little at a time.

If you find that the circular slots in the adjusting plate prevent you from turning the plate for the desired temperature change, remove the two lock screws carefully so that you can move the adjusting plate a full 180°. Replace the two adjusting screws and continue the calibration process as before.

*Timers*. A timer is used to automatically control an appliance or give a warning to the operator that a predetermined time has lapsed. Figure 3-44 shows a typical wiring diagram of an electric range single-pole oven timer.

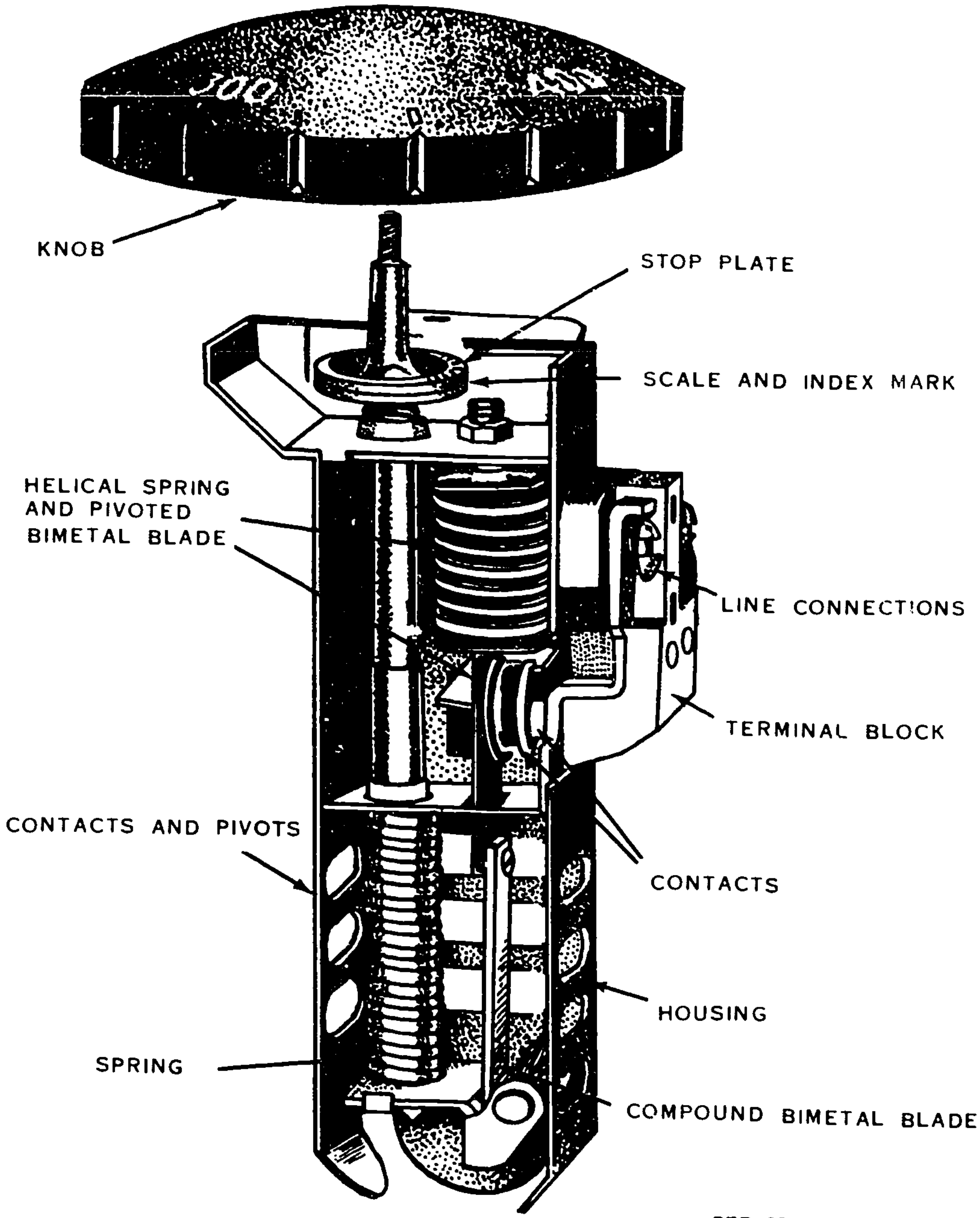



Figure 3-41. Bimetallic blade control.

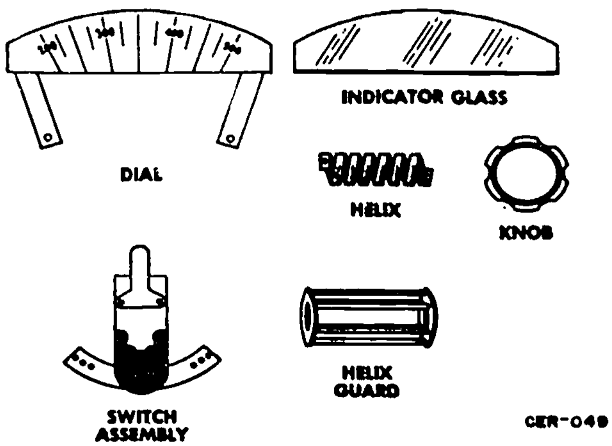


Figure 3–42. Helix components.

**Exercises (435):**

1. What is the purpose of appliance controls?

2. State the two types of switches or controls.

3. List the three types of manual controls.

4. List the four types of automatic controls.

5. What principle of operation does a helix control employ?

6. What type of operation does a bimetallic blade control have?

7. What principle of operation does a hydraulic control use?

**436. State the types and give specific details about open and inclosed heating elements.**

There are many types of heat-producing appliances. Some provide heat for cooking, some for comfort, and some for health. Although these various appliances differ widely in design and configuration, each depends upon a heating element actuated by electricity to operate. A heating element is made from a special wire, normally a combination of several metals. The best known metal is nickel-chromium alloy or nichrome. The element is classed as a semiconductor, which allows current to flow, but with a great amount of resistance. The more current forced through the element by higher voltages, the greater the amount of heat it produces.

There are two general types of electrical heating elements used by the Air Force. The two types are the open (coil or ribbon) and the enclosed (tubular). The specific type depends upon the use for which the element is designed.

**Open Elements.** Open heating elements are used where the material to be heated is dry and the element does not come in contact with anything. The element is made of high- resistance wire, which becomes hot with the passage of electric current. The wire may be either coiled to offer more length and greater heat, or it may be flattened to ribbon form.

*Coil type*. The open-coil heating elements may be mounted on rods (center of fig. 3-45) for use in ovens and space heaters. They may be of the suspended type (bottom of fig. 3-45) supported by porcelain insulators and used in domestic range ovens and space heaters or they may be spiral-wound (top of fig. 3-45) and used in a porcelain brick as a surface heating unit on ranges and the like.

*Ribbon type*. Ribbon-type heating elements, usually wrapped around a mica insulator, are used in small appliances, such as irons and toasters (see fig. 3-46).

*Repair and replacement procedures*. If an open heating element becomes oxidized or brittle, replace the entire coil. If the element is fairly new and is not badly oxidized, you can repair it temporarily until a replacement can be obtained. To repair an element, use one of the following methods:

*a*. Twist together broken ends of the heating element wires and braze the ends with silver solder, using a suitable flux.

*b*. Insert the broken ends in a split washer and pound flat, making sure that you obtain a solid connection.

*c*. Insert the broken ends of the heating element in a nichrome sleeve and flatten the sleeve to insure a solid connection.

**Inclosed Heating Elements.** The inclosed heating elements are used for both surface and immersed heating. They are found in nearly all types of appliances, such as clothes dryers, dishwashers, water heaters, deep fat fryers, and electric ranges. Inclosed elements are made of a high-resistance wire set inside a copper tube or cast in an iron tube to withstand the abuse of heavy cooking utensils. The resistance wire is separated from the tube by an electrical insulating material. This eliminates the possibility of electrical shorts or grounds to anything that comes in contact with the tube.

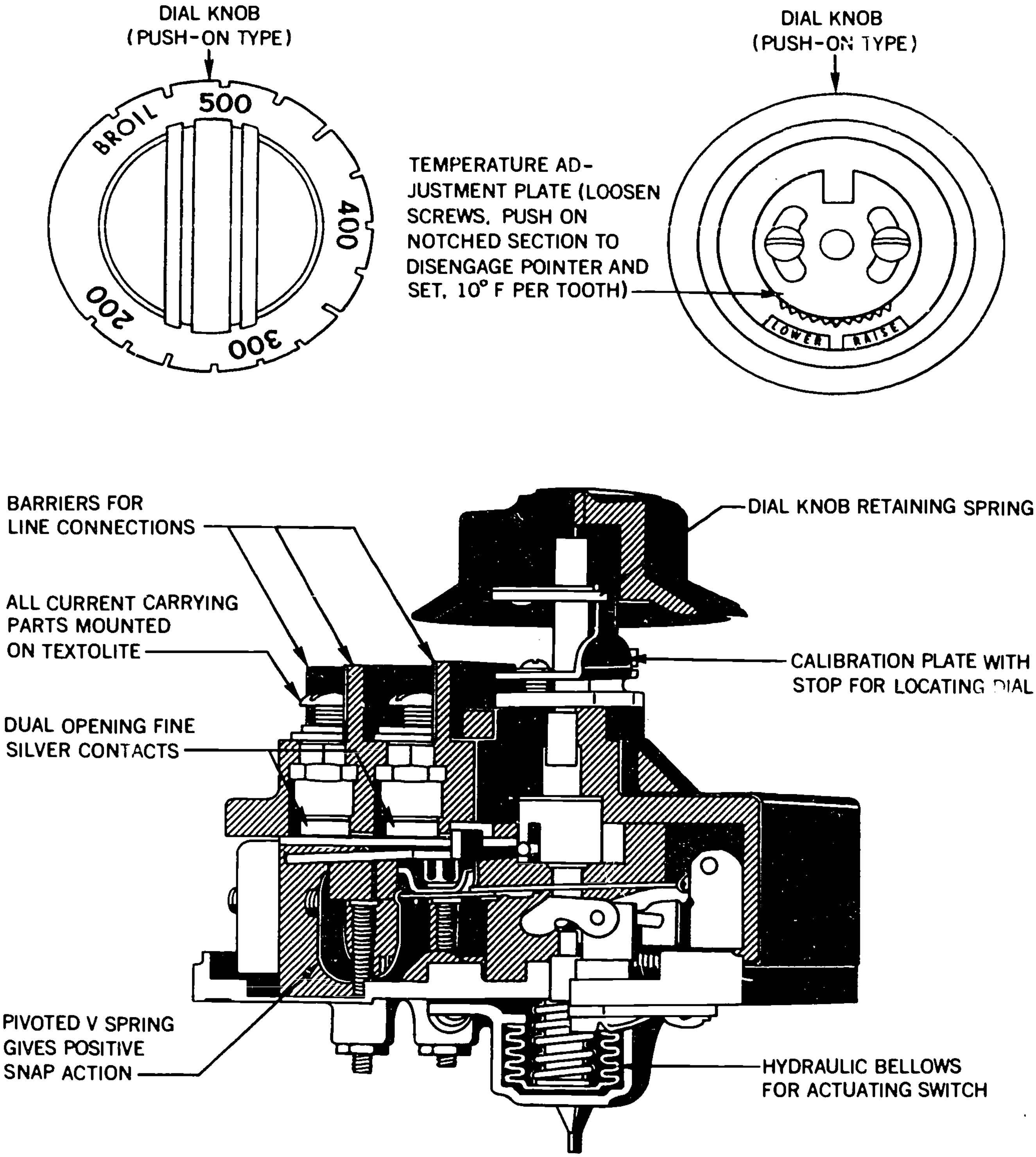



Figure 3–43. Hydraulic controls.

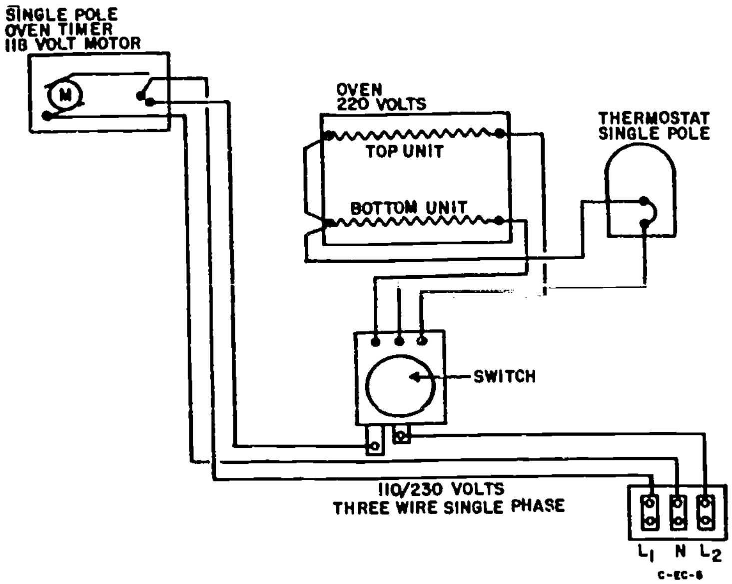



Figure 3–44. Single-pole oven timer wiring schematic.

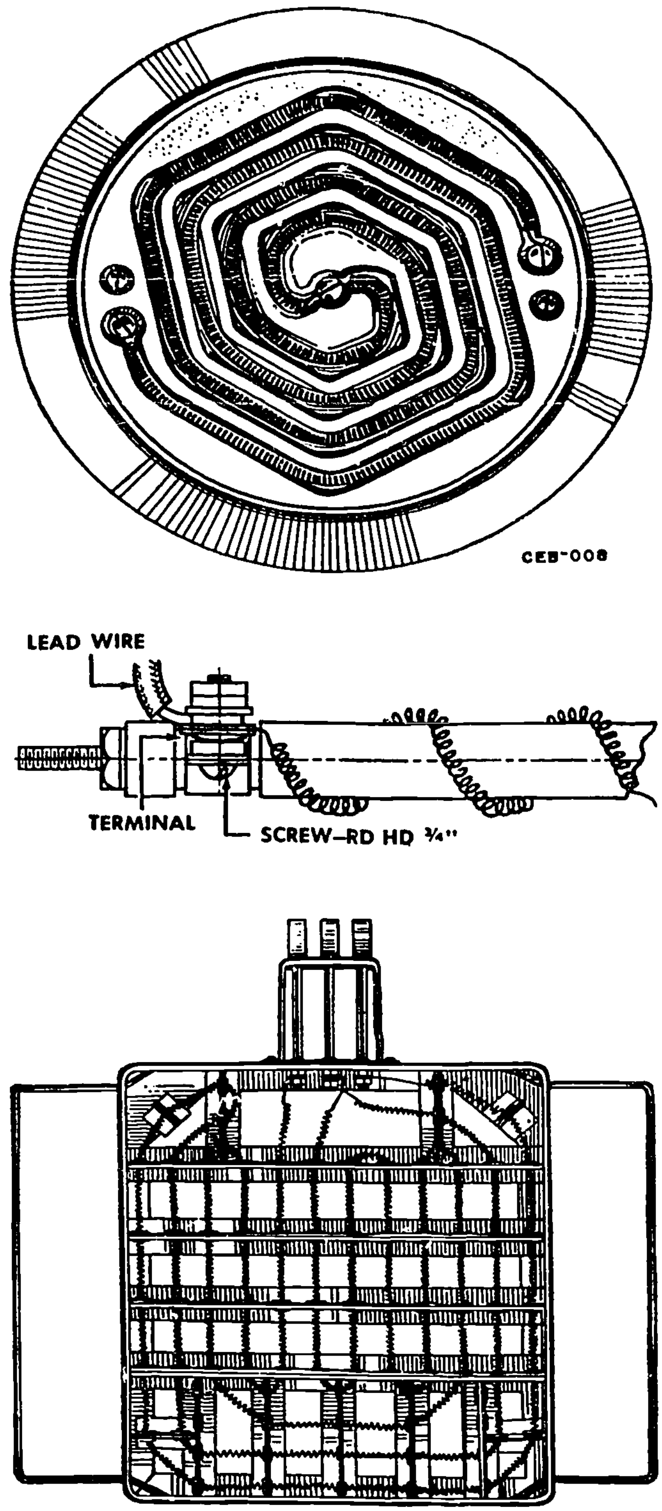



Figure 3–45. Types of open-coil heating elements.

*Surface-cooking type*. Surface-cooking inclosed units are used on domestic ranges and some commercial equipment. The resistance wire is surrounded by an insulating powder and covered with a metallic tube (see fig. 3-47).

*Immersion type*. Immersion-type units are used in water heaters, deep fat fryers, and sterilizers. The resistance wire is surrounded by an insulating powder and covered by a copper tube (see fig. 3-48). Immersion-type elements must be constantly submerged in liquid to prevent damage.

*Repair and replacement procedures*. Inclosed-type heating elements are uneconomical to repair and have to be replaced. Test the elements for opens or grounds before you discard them to be sure they are defective. Opens occur in the elements when they have been damaged by abuse and when excessive voltage has been applied. You can detect this by a lack of continuity across the element. Grounds occur when the resistance wire touches the inclosing tube. They can be caused by rough handling and can be detected by continuity between the terminal and the tube.

**Exercises (436):**

1. List the two types of open heating elements.

2. List the two types of inclosed heating elements.

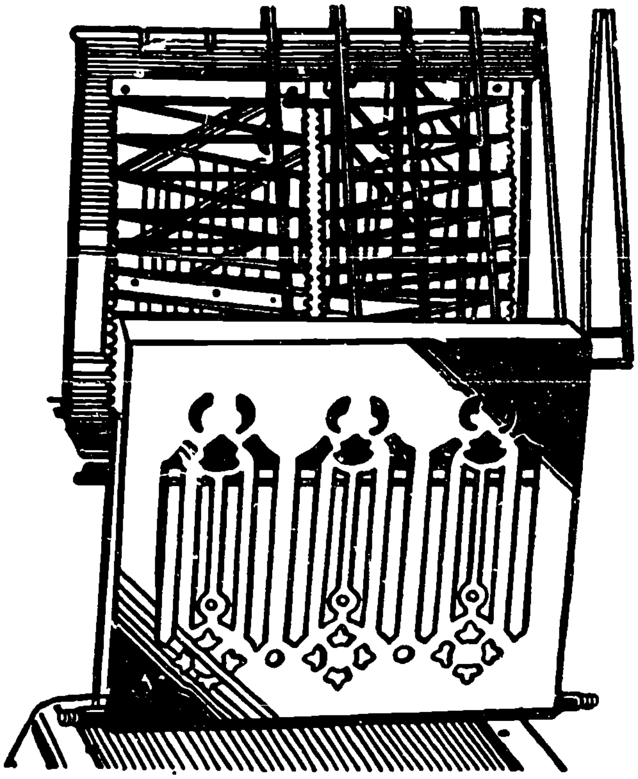
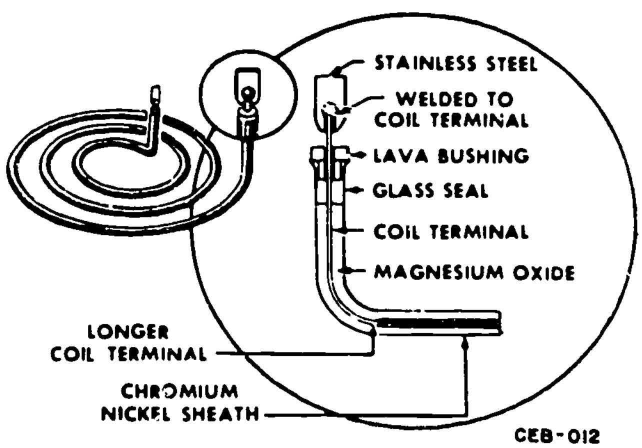


Figure 3–46. Ribbon-type heating element.





Construction of surface cooking elements.

Figure 3–47. Construction of surface cooking elements.

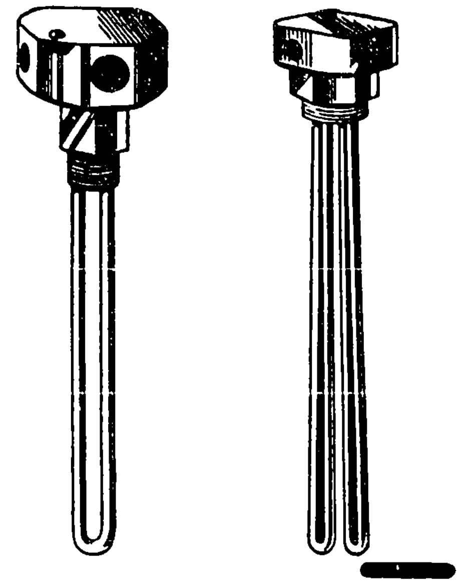


Figure 3–48. Immersion-type elements.

3. In what type of material is the electrical high-resistance wire of an element inclosed?

4. What is the most common alloy of which heating elements are made?

5. Under what conditions should you use open heating elements?

6. What kinds of appliances operate with ribbon type heating elements?

7. What type of sleeve is used to repair an open element?

8. What is the normal procedure to follow when an inclosed heating element is defective?

**437. Identify accurate statements regarding the operating principles of appliances.**

The information on various representative appliances applies generally to a number of different makes and models. You can use these repair procedures for other appliances which you will service. In order to troubleshoot and repair appliances effectively, you must understand their principles of operation. For this reason, we will discuss each appliance briefly before we consider any servicing problems.

**Heating Appliances.** Electric heating appliances used in offices and homes are usually called space heaters. They are used to heat individual rooms and to furnish additional heat to rooms and buildings which already have some installed type of heating system. An electric heater is an ideal means of producing heat for this purpose, because it is clean and easily transported.

There are several types of electric space heaters, including the small portable unit; the larger, permanently installed unit; and the panel type.

*Portable space heater*. The electric space heater most often used is the small portable unit. It is connected to a power source by a flexible cord and controlled manually by a switch. A unit of this type is desirable to heat small offices, single rooms, and baths.

Portable bowl-type electric heaters are the most numerous. This heater contains a coil of resistance wire, usually nichrome, wound on a cylindrical insulator. The heating assembly is positioned in the center of a round reflector bowl which is equipped with a stand and a wire grille. The heat produced is reflected into the area by the reflector bowl.

The portable convection-type heater looks somewhat like a regular floor gas-operated space heater. The heating coils are inside a metal shield. When the heater is in operation, the heated air surrounding the coil rises and is replaced by the cool air from the floor. This action produces a circulation of air through the heater and warms the area.

There is also a small portable unit designed with a heating element and a motor-driven electric fan. The fan causes positive heat transfer from the element to the air. Heaters of this type are generally equipped with a switch which controls both the fan motor and the heating element.

*Common space heater*. The common space heater is larger than a portable unit. It is installed permanently and, depending on the design, may be installed in the floor, wall, or ceiling. It is usually controlled by a thermostat, but it can be controlled manually if desired. This type has a shell, heating element, blower, blower motor, thermostat, and manual switch.

*Panel space heater*. Still another space heater is the panel type. It is used to heat office spaces and small apartments. The heater mounts into a wall and is controlled either manually or automatically. The most common size of panel space heater is approximately 20 inches wide and 60 inches tall, but other sizes are in use. The heater is made up of a reflector; a heating element; a protective guard; and, in some cases, a motor-driven circulating fan or blower.

Electric heaters are designed to operate on 120- and 240-volt AC. Those which operate on 240 volts are usually more efficient. Some of these heaters have a two-heat switch so that the user can select one of two settings.

Most of the space heaters are simple in construction; and if a trouble occurs, it is usually a faulty cord or a broken heating element. The heating element is most often the open coil type, held in position by ceramic spacers or hooks.

**Cooking Appliances.** We will now discuss electric cooking equipment used in domestic quarters, hospitals, and dining facilities in the Air Force. Although the types of equipment used may vary, the basic operating parts of all these appliances are heating elements, switches, and thermostats. Appliances are required to have a nameplate showing the operating voltage and the load, either in amperes or watts.

*Toasters*. Both domestic and commercial toasters have a toasting chamber with heating elements which heat the bread by radiation. Domestic toasters are usually operated manually by a switch or by a timer mechanism; commercial toasters are usually operated by a motor-driven chain conveyor.

*a. Domestic toasters*. Most domestic toasters operate on 120 volts and are connected to the power source by cords and an attachment plug. A mechanical mechanism lowers the bread between the heating elements and also completes the electric circuit to the elements. The bread is toasted to the degree determined by the length of time the mechanism remains in the down position. A spring on the lowering mechanism governs that time. The spring tension is adjusted by a dial on the side of the toaster which determines the color of the toast.

Normally, faulty toaster operation results from improper closing of the contact points. The points may be cleaned with a fine file or sandpaper, and the mechanical linkage may be adjusted for proper operation. Other troubles are loose connections which should be cleaned and tightened and open elements which must be replaced.

*b. Commercial toasters*. Commercial toasters are used extensively in dining halls, where a large quantity of toast is needed. The commercial toaster usually operates on 208-, 220-, or 240-volt single-phase power. The toaster consists of heating elements, a switch, thermostat, conveyor rack, and a small drive motor. The switch controls the power to the motor and heating elements. The motor drives the conveyor rack to carry the bread past the heating elements. The thermostat controls the temperature of the heating elements, thereby controlling the degree to which the bread is toasted.

Figure 3-49 shows a typical commercial toaster diagram. When you are troubleshooting a toaster, check the power supply first. Then check for loose connections and open elements. Element repair is normally confined to replacement. Insure that the power is disconnected when you repair a toaster.

*Deep fat fryers*. Deep fat fryers usually have a tank, one or more heating elements immersed directly in the fat, and a temperature control for maintaining desired cooking temperatures. Cooking temperatures are normally maintained between 240° to 410° F. Temperatures above 410° F. are harmful to frying fats and should never be used.

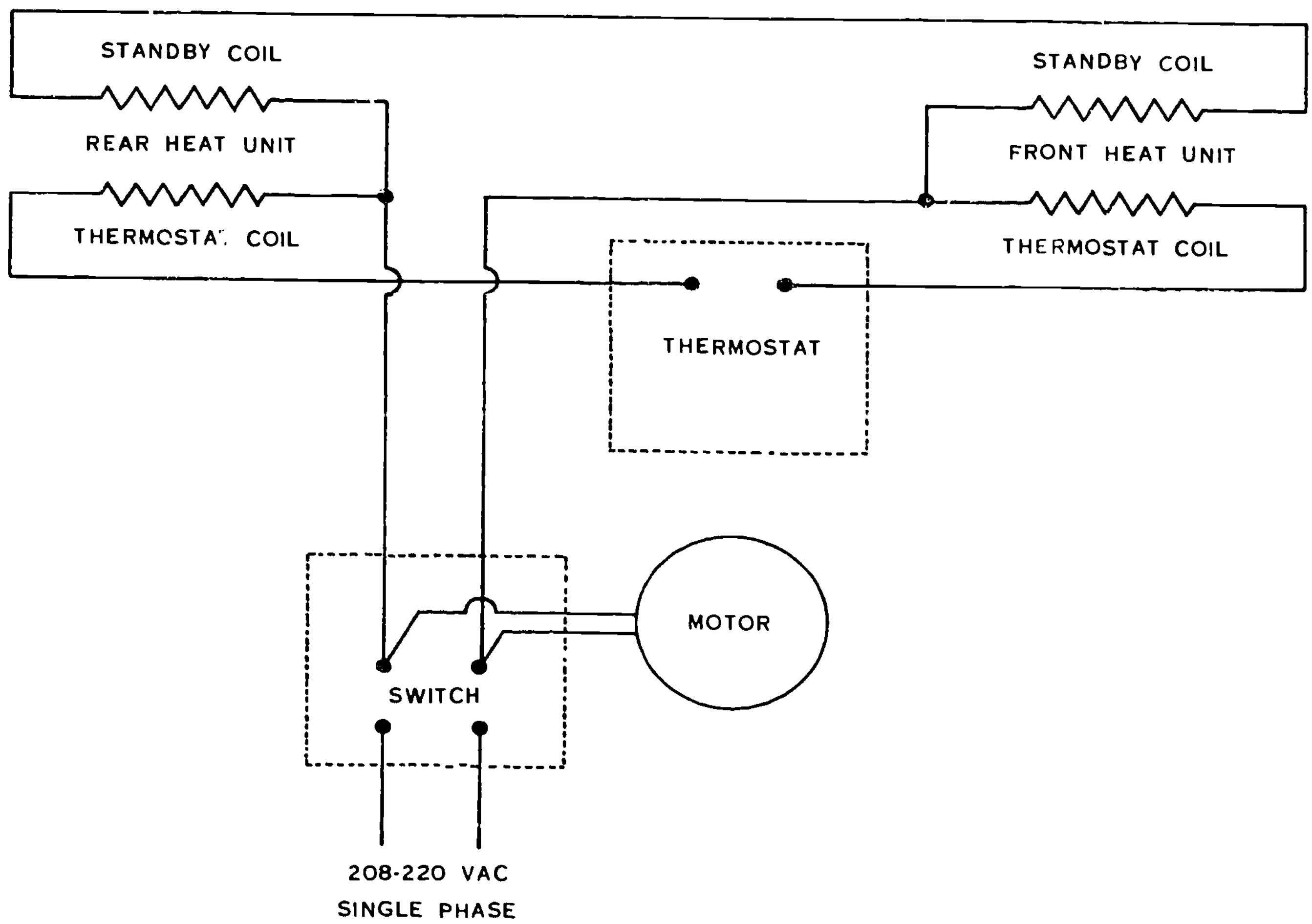



Figure 3–49. Commercial toaster wiring diagram.

The power supply for deep fat fryers is usually 208, 220, or 240 volts and may be a single-phase or three-phase connection. The main parts of a deep fat fryer are a tank, heating elements, a thermostat, a relay, a pilot light, and a safety switch. The tank holds the cooking fat. A tank of normal size holds approximately 28 pounds of fat. The heating elements are put directly into the fat and must be completely covered before the unit is turned on.

The thermostat acts as the main switch and regulates the temperature of the fat. When the thermostat is turned on, power is applied through the safety-limit switch to the relay coil, energizing the relay. When they are energized, the relay contacts close, supplying power to the heating elements. The safety-limit switch protects the heating elements from harm if they are lifted out of the fat before the unit is shut off.

*Electric ranges*. Electric ranges cook food by surface and oven heating elements. The surface elements or burners are on the top of the range, and the oven elements are within the oven. Electric ranges differ in size, but most standard ranges have four surface burners, a deep-well cooker, and an oven. Electric ranges vary in width from the 20-inch apartment size to the 40-inch full size range. The approximate height of the surface burners from the floor is 35 inches.

The primary components of an electric range are the surface burners, deep-well cooker, oven, timer, and individual switches which control the temperatures of the heating units. The range usually has a convenience outlet to supply electricity for a coffee percolator, waffle iron, or toaster, which you can operate on the top of the range. The range is usually automatic. The oven control keeps the temperature of the oven at a set point, and an electric clock and timer shuts off the oven at a predetermined time. The individual switches which control the temperatures of the surface burners are usually located on the front of the range.

The principle of operation of an electric range is simply that of an electric current passing through a resistance, thereby producing heat. The resistance is usually nichrome wire.

Heating elements used in ranges may be of the open or the inclosed types. The surface burners usually have inclosed tubular or cast-in elements. Each element is controlled by an individual switch, which can control the element for as many as 10 different heat positions. The electrical power supply to each element is either 120 volts or 240 volts or both, depending upon the heat position of the switch. Each surface burner is connected to a signal light which indicates when the unit is in the on position. In the wiring schematic in figure 3-50, you can see the wiring of a typical electric range.

The ovens of electric ranges are equipped with open or inclosed elements. These include the rod and coil, suspended coil, spiral-wound or the tubular types. Modern ovens usually have two heating elements. One is located in the upper part of the oven and the other in the lower part.

**Water Heaters.** Electric water heaters have a storage tank, one or two heating elements, insulation, a shell, and one or two temperature controls. The heating elements deliver heat directly to the water and each element has a thermostat, usually located just above it, as shown in figure 3-51. The average temperature setting of the control is 150°

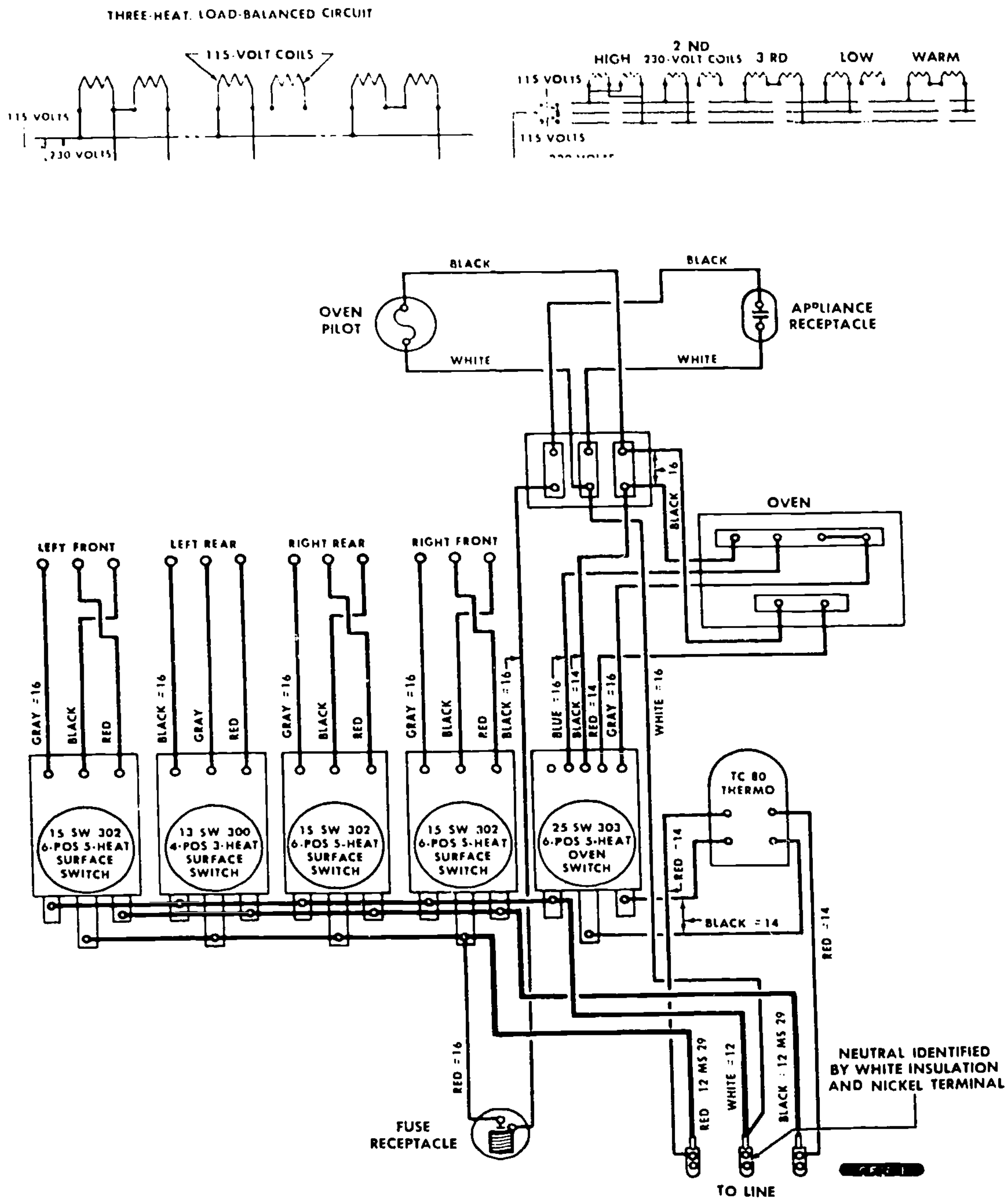



Figure 3–50. Electric range wiring schematic.

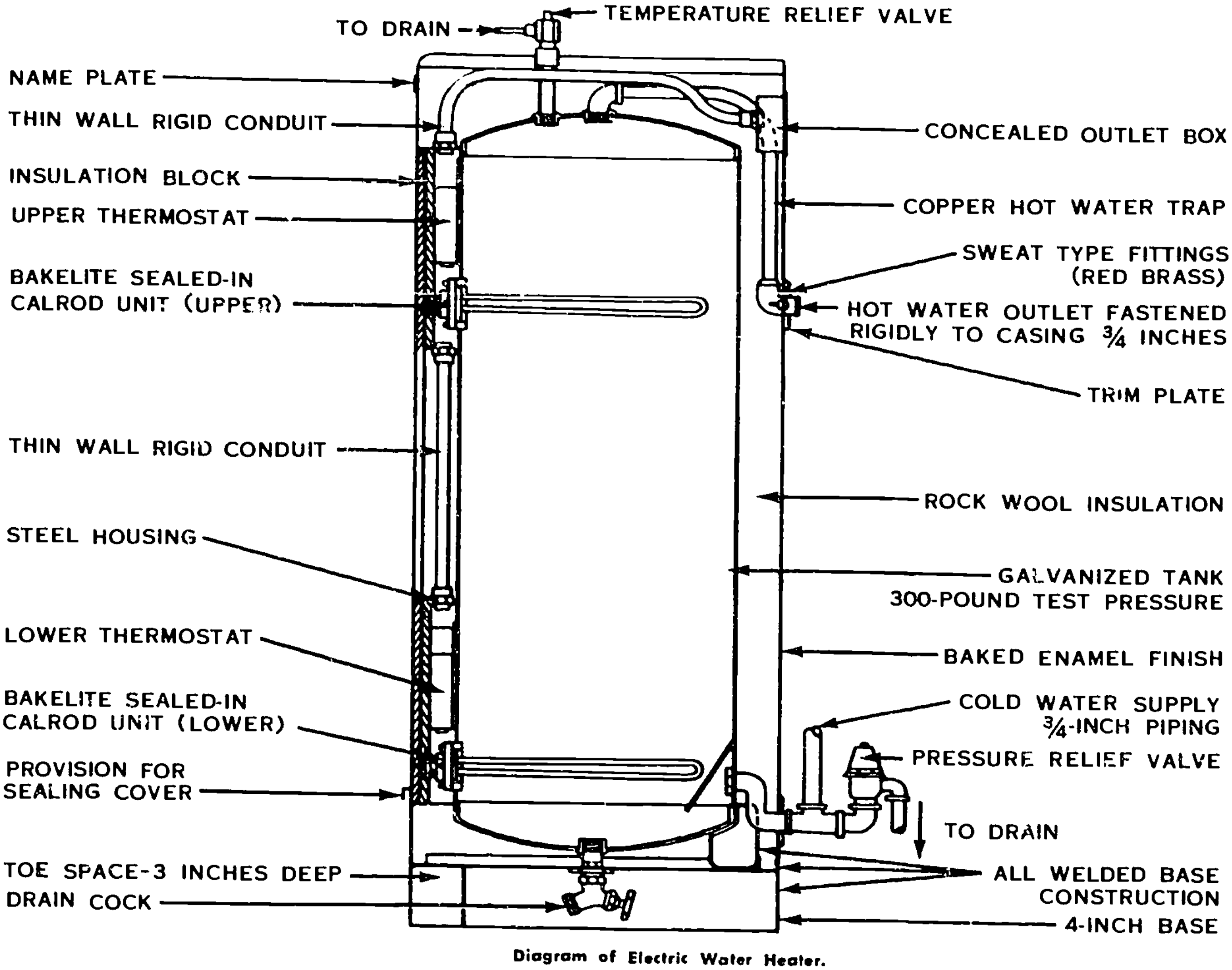



Figure 3–51. Twin-unit water heater.

F., the most desirable water temperature for all purposes. In figure 3-52 you can see the wiring schematic of a dual-element water heater.

**Dishwasher (Clipper).** Clippers are large electrical appliances that are used in many dining halls to wash glass dishes and silverware. See figure 3-53. They usually consist of a hot water tank with a booster for extra hot water, a drive line, usually motor-chain driven, a control panel, and an assortment of electrical switches and temperature devices to insure proper dishwashing. Because of the complex components, we will not go into any great detail in this chapter. We do want you to know that the clipper is maintained and repaired by the electric shop.

**Exercises (437):**

Place a T or F beside each true statement and correct false statements.

_____ 1. Portable space heaters are controlled manually by a switch.

_____ 2. Panel space heaters that operate on 240 volts are usually more efficient than heaters that operate on 120-volt AC.

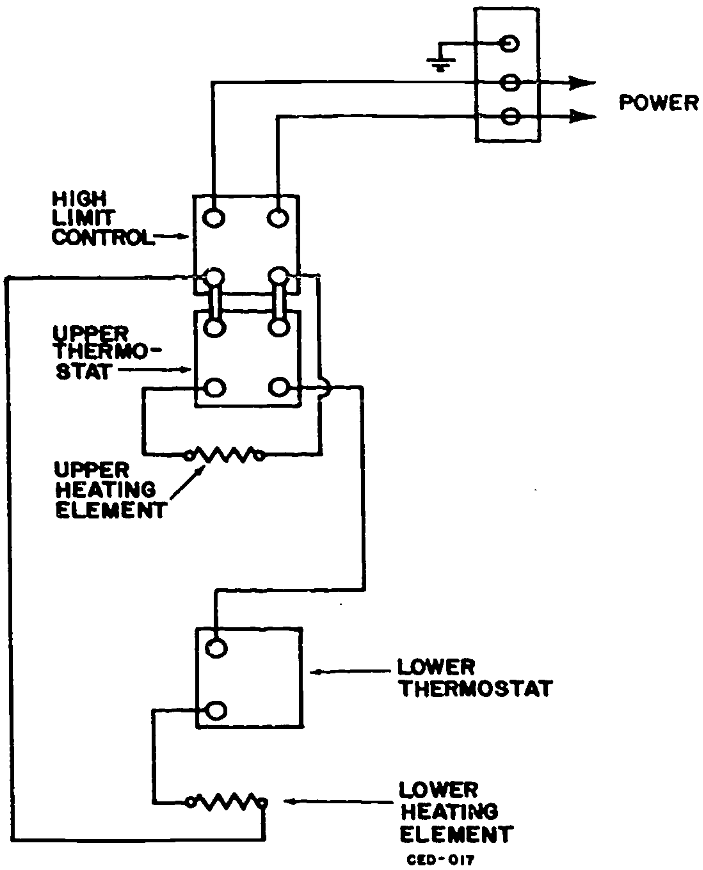



Figure 3–52. Water heater wiring schematic.

_____3. Faulty toaster operation results from improper closing of the contact points.

_____4. Deep fat fryers are regulated by the heating elements, which supply direct heat.

_____5. An electric range operates due to an electric current passing through nichrome wire.

_____6. Electric hot water tanks may contain two heating elements.

_____7. Clippers are maintained and repaired by the electric shop.

**438. Give specific details about the installation and connection of heaters and electric ranges.**

**Installation and Connection of Kitchen Appliances.** Kitchen equipment is connected to a source of power by one of two methods: permanent and temporary. Temporary connections are made by means of a flexible cord attached to a male plug and connected or plugged into a wall outlet. A temporary connection is usually made on low-voltage, portable equipment. Permanent connections are made by wiring the appliance directly to a junction box of the power circuit. A permanent connection is usually made on large, high-voltage, stationary equipment.

**Installation of Heaters.** When you install an electric space heater, refer to the information from the nameplate for proper installation. Each unit of heating equipment should have a nameplate giving the identifying name and the normal rating in volts and amperes, or in volts and watts. Heating equipment for use on AC only or DC only must be so marked. Heaters equipped with motors over 1/8 horsepower should state the rating of the motor in volts, amperes, and frequency, and the heating load in volts and watts or amperes.

*Portable space heaters.* Usually portable heaters are connected to a source of power through a power cord with a two- or three-prong male plug. The cord must be of the approved type for its location. Cords for heaters located in damp places must be one of the following types of insulation:

*a.* AFSJ or AFS: insulation of impregnated asbestos, with an outer covering of rubber.

*b.* HSJ: insulation of rubber with asbestos or all neoprene, with an outer covering of cotton and rubber.

*c.* HSJO, HS, or HSO: insulation of rubber with asbestos or all neoprene, with an outer covering of cotton and oil-resistant compound.

Cords for portable heaters located in dry places are type HPD, an insulation of rubber with asbestos or all neoprene, with an outer covering of cotton or rayon. The cord should have one conductor for use as grounding which can be easily distinguished from the other conductors. Its normal color is green. It should be no smaller than No. 14 AWG copper wire, except that, when the current-carrying conductors are smaller than No. 14 AWG, the ground should be the same size as the current-carrying conductors.

*Fixed heaters.* The ampere rating of branch circuit conductors used to supply fixed space heaters, which consist of resistance elements with or without a motor, should be figured on the basis of 125 percent of the total load of the motor and the heater. All fixed electric space heaters must be provided with a means for disconnection from all ungrounded conductors.

Heaters should not be placed where they are exposed to severe physical damage unless they are adequately

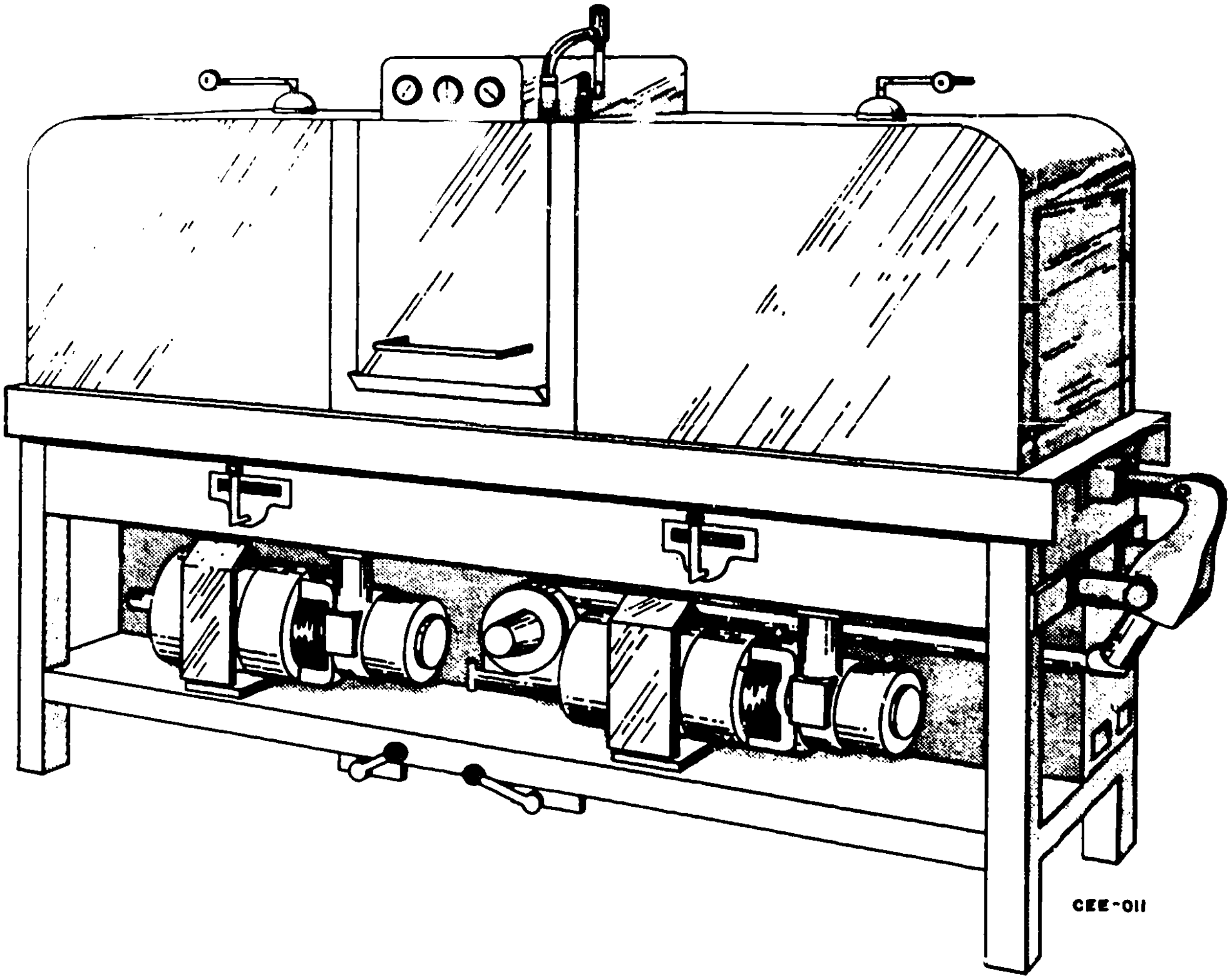



Figure 3–53. Dishwasher.

protected. If they are used in damp or wet locations, they must be approved for such use and must be constructed and installed so that water cannot enter or accumulate in wireways, electrical components, or duct work. All non current-carrying parts that can become energized must be bonded together and positively connected to a continuous No. 14 AWG (or larger) covered copper wire extending to the distribution panelboard. When the bonding conductor is subject to physical damage, it must be at least a No. 10 AWG copper. Before connecting the space heater to the power source, make sure that the circuit is off.

**Installation of Electric Ranges.** When you install a range, first determine the number of watts that the range will use if all the surface burners and the oven are on at the same time. The number of watts depends upon such factors as type, size, construction, make, etc. A less expensive range is likely to use more watts because the oven may not be too well insulated and the burners may not be of the economy type. To determine the wattage used by an electric range, look at the namep' ·. An electric range usually consumes from 800 to 16,000 watts. For this reason, ranges should be on a special circuit between the building "service entrance" and the range.

The size of the range cable depends upon the kilowatt rating of the range. The cable usually carries two No. 6 or No. 8 wires, with a neutral wire one size smaller. A No. 8 wire is the smallest permitted for 8¾ kW and larger ranges.

An electric range usually requires a 50-ampere circuit. It must be protected by a 50-ampere overcurrent protection device. All receptacles, switches, and sockets for a 50-ampere circuit must have a rating of 50 amperes.

Before you plug in the power cord of a range, be sure that all the controls are in the OFF position and that the range circuit is deenergized. With the circuit "dead," plug in the range and turn on the circuit switch. This method prevents possible arcing at the prongs of the male plug and the wall outlet. This arcing would occur if most of the burners were in the ON position. After a range is installed, perform an operational test to check its operation.

**Other Appliances.** The installation of all appliances must meet the standards of the National Electrical Code and the manufacturer's requirements. To try to discuss each installation at this time would require more time than we have. One thing to think about when in 'ling any appliance is the size of the wire, which must be large enough to carry the load of the appliance. All conduit must be run in a good workmanship type manner a be of proper size to house the conductors. A determination must be made as to whether a permanent or temporary connection should be made with the appliance.

**Exercises (438):**

1. Before installing an electric space heater, where should you look for information about the voltage of the heating equipment?

2. How is the grounding conductor of a cord for a portable space heater distinguished from the other conductors?

3. When installing a conductor to a fixed heater, what percentage of the load should the conductor carry?

4. What is the watt consumption of an electric range?

5. On what does the size of a range cable depend?

6. What size wire would normally be installed to an electric range?

7. What requirements apply to an electric range with a 50-amp circuit?

8. Why must you be sure to deenergize a range circuit and have all controls in the OFF position before plugging in the power cord?

**439. Restate specific details concerning repair of and troubleshooting procedures for appliances.**

**General Troubleshooting.** A bad appliance should first be checked visually. If a visual inspection fails to find the trouble, a meter is an indispensable device in testing electrical circuits of appliances.

When you attempt to repair an inoperative appliance, do not be in a hurry to disassemble it to find the trouble. You should first pull the power cord male plug from the wall outlet and then determine if there is current at the outlet. If the outlet is energized, inspect the power cord. Next, examine the male plug connections for cleanliness and tightness. Finally, inspect the power cord for any broken wires at points where the cord is most likely to bend. Also, check the insulation on the power cord. If the condition of the cord makes it unserviceable, you should replace it before going any further in your troubleshooting procedure.

Checking the power supply and the condition of the power cord should be the first thing you do when you attempt to find an electrical fault in an appliance. In a number of cases, electrical faults are found in the power cord rather than in the appliance itself. Only when you have determined that the fault is not with the power supply or the power cord should you consider troubleshooting the internal units. To troubleshoot these units effectively, you may have to disassemble part of the appliance.

In your troubleshooting and repair work, treat electricity with respect. Working with electricity is hazardous and you must take every precaution to avoid electrical shocks, burns, and even electrocution. Regard all circuits as live until you have opened the switches or have made a voltage test and know that the circuit is dead. Lock all switches which have been opened in the OPEN position and remove protective devices, such as fuses, from the holders. As an added precaution, it is good practice to tag the switches, fuses, and other protective devices to keep other personnel from tampering with them and creating a safety hazard.

**Troubleshooting Heaters.** Before troubleshooting the internal components of an electrical space heater, determine if there is voltage at the wall outlet. Next, examine the male plug terminal connections for cleanliness and tightness. Then inspect the power cord for broken conductors. Perform a continuity check on the power cord to make sure that it is all right. If you have the proper voltage at the outlet and the power cord is serviceable, then you are ready to test the internal components of the heater.

Remove the grille and examine the heating element for breaks. All heating elements that are replaceable in the field and are a part of an electric heater must be legibly marked with the ratings in volts and amperes or in volts and watts. If a visual inspection does not reveal any breaks in the element, then perform a continuity test on it. Also, check the element's terminal screws for corrosion and looseness. You may find an open at these points. Next, check the operation of the thermostat and switches. Opens may be found at these points too. If you find any opens in these control devices, you should dress the contact points with a strip of cardboard or a burnishing tool. If the blower motor is inoperative, your trouble may be in the motor, the motor circuit, or the control circuit.

TABLE 3–2
TROUBLESHOOTING GUIDE FOR ELECTRICAL RANGES

| *Trouble* | *Probable Cause* | *Remedy* |
|---|---|---|
| Range will not heat. | No voltage at outlet. | Correct voltage. |
| | Blown fuse. | Replace fuse. |
| | Open breaker. | Reset breaker. |
| | Broken wire in power cord. | Check continuity of cord. |
| | Faulty wall outlet. | Check for voltage at outlet. |
| | Faulty prongs on male plug. | Replace if necessary. |
| | Faulty slots in wall outlet. | Replace if necessary. |
| No heat at one surface burner. | Loose terminal connections at burner unit. | Clean & tighten connections. |
| | Corroded contacts in control switch. | Clean contacts with sandpaper. |
| | A burned-out element. | Replace element. |
| | Open in burner circuit. | Replace wires if necessary. |
| Surface burner too hot. | Incorrect or reverse connections. | Switch wires as required. |
| No heat in oven. | Element connections loose and corroded. | Clean & tighten connections. |
| | Burned-out element or elements. | Replace elements. |
| | Inoperative oven control. | Adjust or replace control. |
| Oven too cool. | Inoperative oven control. | Adjust and replace control. |
| | Improper voltage at element. | Check increase voltage. |
| | Open in one section of element. | Check and replace voltage. |
| | Loose and corroded element connections. | Clean and tighten connections. |
| Oven too hot. | Inoperative oven control. | Adjust or replace control. |
| | Wrong element. | Install proper element. |
| Uneven baking. | Range tilted. | Level range. |
| | Oven racks not on proper supports. | Place racks on proper supports. |
| Appliances fail to heat when plugged into appliance outlet. | Blown fuse or tripped circuit breaker. | Replace fuse or reset breaker. |
| | Loose and corroded circuit connections. | Clean and tighten connections. |
| | Broken circuit wires. | Replace wires. |
| | Faulty outlet. | Replace if necessary. |

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**Troubleshooting Motor-Driven Appliances.** The three main sources of trouble in motor-driven appliances are the power connections, switches, and motor field windings. Check all power connections for a bad male plug, broken or shorted flexible cord, and loose or dirty connections. Check the switch for a broken case, making and breaking of the contacts, and loose and dirty connections.

Check the motor for opens, shorts, and grounds if it is inoperative. Tighten all loose connections. Clean all dirty connections. If the motor cannot be readily repaired, install a substitute or replacement motor.

**Exercises (439):**

1. What is the first check you should do to an inoperative appliance?

2. What type of test should you perform if a visual check does not reveal any opens in a heating element?

3. What is the first thing you should do when attempting to find an electrical fault in an appliance?

4. What is the probable cause when a burner on an electric range gets too hot?

5. What is the most common repair of electric ranges?

6. What are the repair procedures when troubleshooting toasters?

Use the troubleshooting guides in table 3-1 to determine the probable cause and remedy for electrical space heater troubles.

After you have found the faulty unit in an electric space heater, repair or replace it. Before you begin to repair the heater, disconnect it from the power source. Since the construction of an electric space heater is simple, you should have very little difficulty in removing any of its faulty components. Usually, you will have to remove the grille before you can replace any internal components. The use of a manufacturer's repair manual is very helpful when you work on an electric space heater.

**Troubleshooting Toasters.** Trouble in this unit is usually in loose or burned connections, damaged relay coils and contacts, or opens in the heating elements. There is no repair procedure for these heating elements. They must be replaced if they are inoperative.

**Troubleshooting Electric Ranges.** When an electric range is malfunctioning and blows out the main fuses, do not replace the fuses until the fault is located. A faulty condition of this type should reveal an electrical "short" or "ground" in one of the surface burners, oven coils, or auxiliary circuits. After completely deenergizing the range, inspect the wiring for abraded insulation and crossed wiring. If you replace some of the wiring, use only wire that is covered with a heat-resistant insulation.

When electrical power is not getting to the range at all, look for an "open" in the main circuit. Consider the electrical power at the range outlet and the condition of the range power cord. Be sure you have proper contact between the prongs of the male plug and the cord and the slots in the outlet.

Since there are many different faults which cause an electrical range to malfunction, refer to table 3-2 to help you with troubleshooting procedures. This table is by no means complete, but should assist in your search for the malfunction.

*Repair procedures*. The most common repair of electric ranges is the replacement of burned-out heating elements. Replacement procedures for all makes and models are identical, although the position on the range may vary.

To remove a heating element from an electric range, first disconnect the range from the electrical power supply. Next, lift the heating element from the range. Now tag the element leads, if necessary. When the terminal blocks and wires are color coded, the above procedure is not necessary. Finally, detach the lead from the element. Install it, reversing the disassembly procedure. After the burner is in place, connect the range to the wall outlet and perform an operational test on the new surface burner. Usually, any one of the surface burner control switches can be removed without bothering the others.

Problems which you are likely to find in oven components are burned-out coils, broken ceramic insulators, and loose and corroded connections. If you are replacing a burned-out element, remove the complete assembly from the oven. When you get the coil assembly out where you can work on it conveniently, replace its faulty parts.

After the oven element is installed, see that the thermostat is set at the OFF position before you turn on the electric power to the range. Perform an operational test on the new element.

TABLE 3–1
TROUBLESHOOTING GUIDE FOR ELECTRICAL SPACE HEATERS

| *Trouble* | *Probable Cause* | *Remedy* |
|---|---|---|
| Heater blows fuse. | Fuse too small for load. | Install fuse of proper rating. |
| | Short in heater. | Repair short. |
| | Ground in heater. | Repair ground. |
| | Shorted blower motor. | Replace motor. |
| Main switch is defective. | Contacts out of alignment. | Align contacts. |
| | Broken spring. | Replace switch. |
| | Frozen contacts. | Replace switch. |
| Element will not heat but blower runs. | Loose element connections. | Tighten connections. |
| | Corroded element connections. | Clean connections. |
| | Defective thermostat. | Replace thermostat. |
| Element heats but will not run. | Defective blower motor. | Replace blower motor. |
| | Loose motor circuit connections. | Tighten connections. |
| | Corroded motor circuit connections. | Clean corroded connections. |
| | Broken motor circuit wiring. | Repair wiring. |
| | Inoperative switch or thermostat. | Repair switch or thermostat. |
| Blower motor operates too slowly. | Improper voltage. | Correct voltage. |
| | Defective blower motor. | Replace motor. |
| | Defective blower motor wiring. | Replace wiring. |
| | Defective blower motor switch. | Replace switch. |
| | Defective thermostat. | Replace or repair thermostat. |

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7. What procedure should you follow in the event there is an open in the thermostat or switches of a heating element?

8. What are the three main sources of trouble in motor-driven appliances?

**440. State troubleshooting, inspection, and maintenance procedures for controls and elements on appliances.**

**Inspecting and Maintenance of Controls and Elements on Appliances.** It is the responsibility of the electrician to make sure switches and elements used on appliances operate properly. This can be done by developing a good inspection and maintenance plan. Periodically, check for loose connections, burned or pitted contacts, and the proper switch mounting. You should also check for good connections, proper mounting, and loose or broken insulators on coil or ribbon elements.

The inspection and maintenance of switches and elements go hand in hand; and in most cases, a problem discovered during inspection is corrected on the spot and requires no further work until the next inspection.

**Troubleshooting Controls and Elements.** Look out for control devices and elements. They will most likely be your biggest problem.

*Switches and controls.* Check switches and controls for making and breaking of contact with an ohmmeter. If the switch is ON, the ohmmeter should read "0." The operation of a switch can also be checked with a voltmeter. Check for voltage input and voltage output.

New switches are usually so inexpensive that repairing an old one is not economical. The contacts may be reformed as a temporary measure to make sure a positive contact is made for completing the electric circuit. Lubricating the contacts and spring mechanism with nonoxide grease reactivates switch operation.

Repair of the bimetallic blade control is limited to an adjustment in the temperature setting of the control to agree with the temperature recorded in the appliance or equipment being tested. Temperature of equipment should be tested by a reliable temperature tester or a good thermometer.

Repair of the helix control is limited to adjustment of temperature setting of the control to agree with the temperature recorded in the appliance or equipment being tested. If the control cannot be adjusted, the complete control assembly must be replaced.

*Timers.* If a timer fails to operate, use the following procedures to locate the trouble.

*a.* Test electric circuit for blown fuse.

*b.* Check for friction between hands of timer and timer crystal.

*c.* Check all wire connections.

To repair the inoperative electric timer, perform the following:

*a.* Replace blown fuses with fuse of proper rating.

*b.* Replace complete rotor if rotor is inoperative.

*c.* Replace complete coil assembly if field coil is burned out.

*d.* Repair timer switch assembly by cleaning contacts or reforming the contact arm to insure positive contact. If contact shows excessive wear, replace switch assembly.

*e.* Adjust hands of timer if hands of timer are binding.

*f.* Check all connections at back of timer for positive contact to make sure the circuit is complete.

*Elements.* An element can be checked using a voltmeter or ohmmeter. If a voltmeter is being used, remove one wire from the element and check for voltage between the empty terminal and ground. A voltage reading indicates a good element, and no voltage indicates an open or defective element.

If an ohmmeter is used, first make sure the power has been disconnected. Remove both conductors to prevent false readings. Connect the two leads of the ohmmeter to the two terminals of the element. A reading of "0" indicates a good element. A reading of infinity indicates an open element.

**Exercises (440):**

1. When performing a switch inspection, what should an electrician check for?

2. How can you reactivate a faulty switch?

3. How should you repair a helix control?

4. When testing a heating element with an ohmmeter, what does a reading of 0 indicate?

# Cathodic Protection Systems

THE AIR FORCE with its worldwide commitments must not have its mission jeopardized because some vital system is rendered unserviceable by corrosion. Since we cannot always immediately replace corroded equipment, corrosion is a problem of great concern at all Air Force bases.

## 4-1. Corrosion

Corrosion is difficult to control. Each metal structure used by the Air Force has its own corrosion problems. This section is designed to be helpful in the basic sciences related to corrosion. It should help you in anticipating, diagnosing, and dealing with corrosion problems.

**441. Define corrosion, explain the components and terms relating to it, and describe how the corrosion process takes place.**

**Corrosion.** Corrosion is the gradual destruction of a material, usually a metal, by chemical or electrochemical reaction with its environment. Corrosion occurs by an electrochemical process. This is similar to that which takes place when a carbon-zinc (dry) cell generates a direct current. Basically, an anode (negative electrode), a cathode (positive electrode), an electrolyte (corrosive environment), and a metallic circuit connecting the anode and the cathode are required for corrosion to occur. We will discuss these terms one at a time.

*Anode.* The term "anode" is used to describe that portion of the metal surface that is corroded and from which current leaves the metal to enter the solution. Let us consider what takes place at the anode when corrosion occurs. Positively charged ions of metal leave the solid surface and enter into the solution. They leave negatively charged ions which are able to flow through the metal.

The ions can bear one or more positive charges. In the corrosion of iron, iron atoms become ions carrying two positive charges, throwing off electrons as shown in figure 4-1. These electrons travel through the metal or an external electrical conductor to complete the circuit at the cathode, where a corresponding reaction consumes these electrons.

*Cathode.* The term "cathode" is used to describe the metal surface from which current leaves the solution and returns to the metal. This is taking place at the same time as at the anode. The electrons generated by the formation of metallic ions at the anode have passed through the metal to the surface of the cathode areas immersed in the electrolyte. Here, they restore the electrical balance of the system by reacting with and neutralizing positive ions such as hydrogen ions in the electrolyte. Hydrogen ions are changed to atoms, and these often combine to form hydrogen gas by their reaction with the electrons at a cathode surface. This change of hydrogen ions at the cathode surfaces will disturb the balance between the acidic hydrogen ($H^+$) ions and the alkaline hydroxyl ($OH^-$) and make the solution less acid or more alkaline in this area, as shown in figure 4-2.

*Electrolyte.* A solution capable of conducting electricity is called an electrolyte. Its ability to conduct electricity is due to the presence of what we called ions. These are positively or negatively charged atoms or groups of atoms in a solution. Pure water, as shown in figure 4-3, contains positively charged hydrogen ions ($H^+$) and negatively charged hydroxyl ions ($OH^-$) in equal amounts.

*Metal circuit.* The circuit is completed outside the solution through the metal or through a conductor joining two pieces of metal. The essential components are shown in figure 4-4. The dots represent electricity (galvanic current) flowing in the solution from the anode (−) to the cathode (+) and returning from the cathode to the anode through the metal wires.

For ease of discussion, the anodes and cathodes involved in a corrosion reaction are called electrodes. The electrodes may consist of two different kinds of metal, or they may be different areas on the same piece of metal. The negative electrode (anode) is where corrosion occurs.

Briefly then, for corrosion to occur, there must be a formation of ions and release of electrons at an anode surface and acceptance at the cathode surface of the electrons generated at the anode. This acceptance of electrons can take the form of neutralization of positive ions or the formation of negative ions. The anode and cathode reactions must go on at the same time and at equal rates. However, corrosion occurs only at the anodes. This loss of anode material is galvanic corrosion, as shown in figure 4-5.

*Simple cell corrosion.* So far we have described the reactions (results) which take place in a simple cell. This process causes pitting and is the main concern of cathodic protection.

Figure 4-6 shows an example of simple cell corrosion on an iron pipe. This can take place between two soils of different moisture content. If at one point there is moist soil and at another point dry soil, the conditions are excellent for a corrosion cell to start. The iron ions pass from the anode into the electrolyte, which in this case is the moist soil. The electrons flow along the pipe to the cathode to unite with hydrogen ions. Figure 4-7 shows a cell being formed in one spot. Impurities in the iron itself cause the corrosion to start.

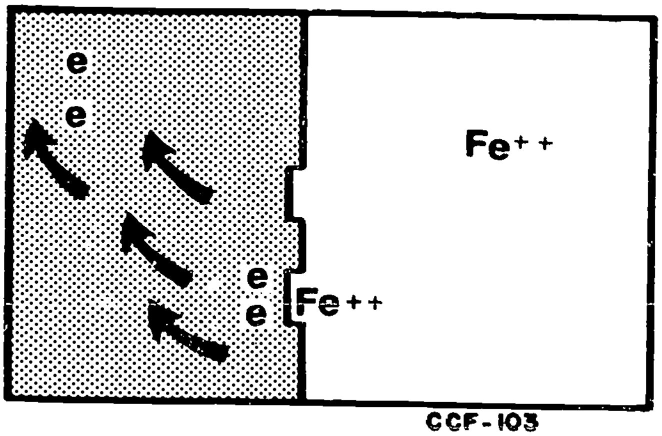


Figure 4–1. Release of electrons from anode.

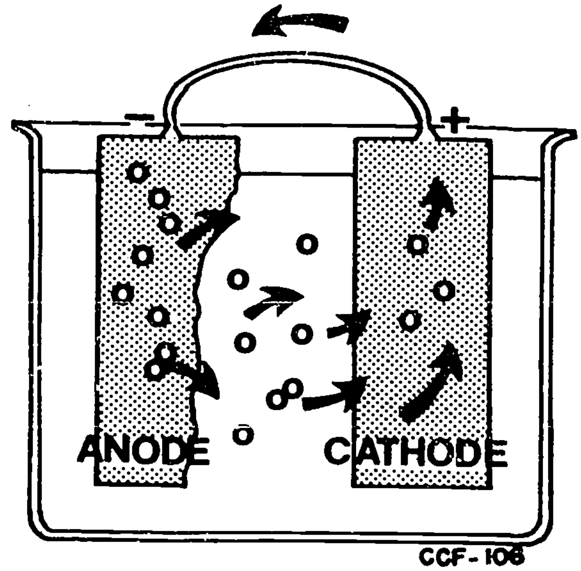


Figure 4–4. Current flow between an anode and a cathode.

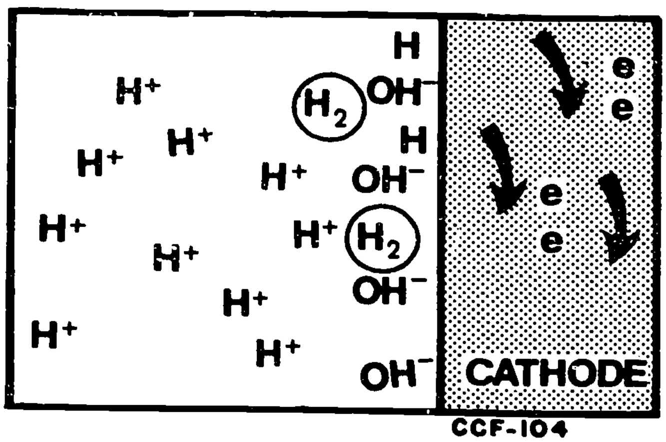


Figure 4–2. Forming of hydrogen atoms at cathode.

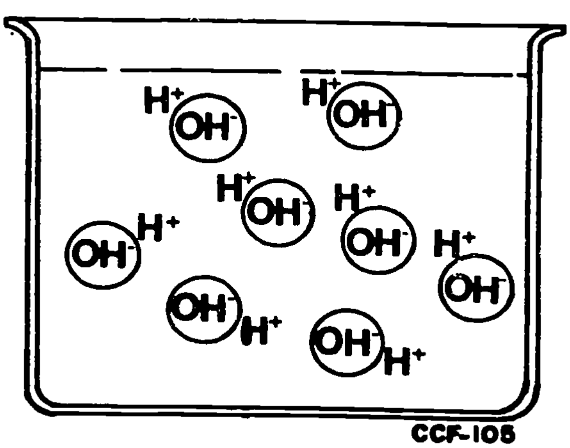


Figure 4–3. Hydrogen ($H^+$) and hydroxyl ($OH^-$) ions in water.

**Exercises (441):**

1. Define corrosion.

2. List and explain the four components necessary for corrosion.

3. Describe simple cell corrosion.

**442. Identify the characteristics of corrosion.**

**Forms of Normal Corrosion.** The three basic forms of normal corrosion that commonly occur on underground steel pipelines and inside fuel or water storage tanks are: (1) general corrosion (uniform attack); (2) galvanic corrosion (dissimilar-metal corrosion); and (3) concentration-cell corrosion. These forms of corrosion are referred to as normal corrosion. We will begin our discussion with general corrosion.

*General corrosion*. General corrosion is the uniform anodic dissolving of metal over the entire exposed surface area. The corrosion rate is nearly constant at all locations. Microscopic anodes and cathodes, which are continuously changing their electrochemical behavior from anode to cathode and cathode to anode, are believed to provide the corrosion cells for uniform attack. Underground steel pipelines can be expected to deteriorate by general

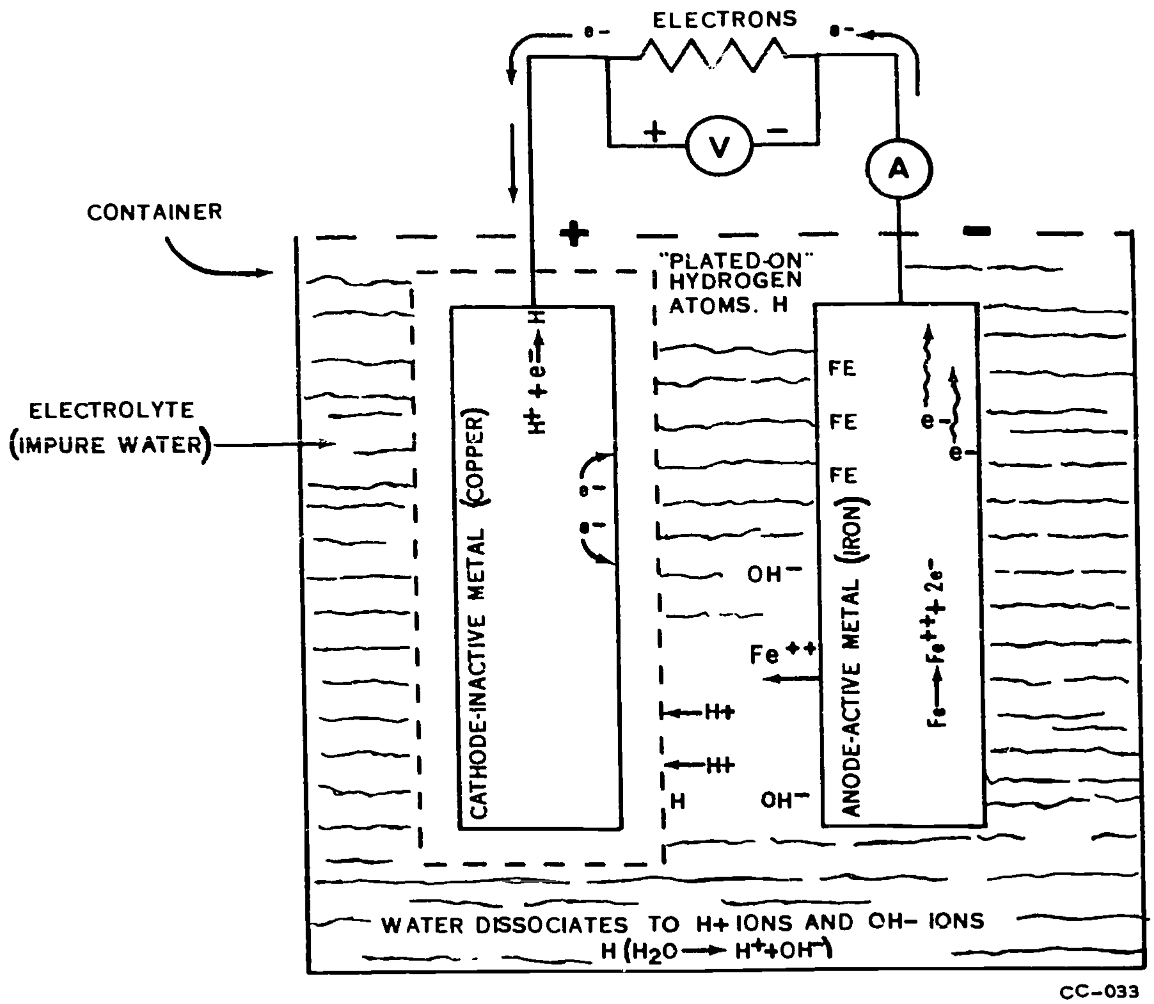


Figure 4-5. Simple cell of inactive metal and iron.

corrosion at reasonably rapid rates when they are exposed to low-resistivity, aggressive soils. For example, steel pipelines exposed to soils having resistivities less than 1,000 ohm-cm can be expected to develop corrosion leaks in times as short as 5 years.

*Galvanic corrosion*. Galvanic corrosion will generally occur if two electrochemically-dissimilar metals or alloys are metallically connected and exposed to a corrosive environment. The less noble material (anode) suffers accelerated attack and the more noble metal/alloy (cathode) is cathodically protected by the galvanic current. The anode-cathode relationship is always the same for any two materials. For example, if iron and magnesium are the electrodes, iron is always the cathode and magnesium is always the anode. But, if iron and copper are placed in an electrolyte, iron becomes the anode and copper becomes the cathode. This means that, in an iron-magnesium cell, the magnesium corrodes; in an iron-copper cell, the iron corrodes. These three metals can be listed in the order of their anode-cathode relationship, as follows:

ANODIC OR CORRODED END
Magnesium
Iron
Copper
CATHODIC OR PROTECTED END

This list, for a given electrolyte, is known as a gal vanic series and tells which of two materials is the anode and which is the cathode in that particular electrolyte. A galvanic series for metals in sea water is shown in table 4-1. This galvanic series can be used for most situations occurring at Air Force installations. Table 4-1 lists magnesium at the top of the chart. This indicates that magnesium corrodes readily. Therefore, to protect a certain metal, you must choose a metal listed higher on the table.

There is no absolute value of the electropotential of a metal outside the factors that influence the corrosive characteristic of the solution in which the potential is measured. Values of potential can change from one solution to another or in any solution when influenced by such factors as temperature, aeration, and velocity of movement.

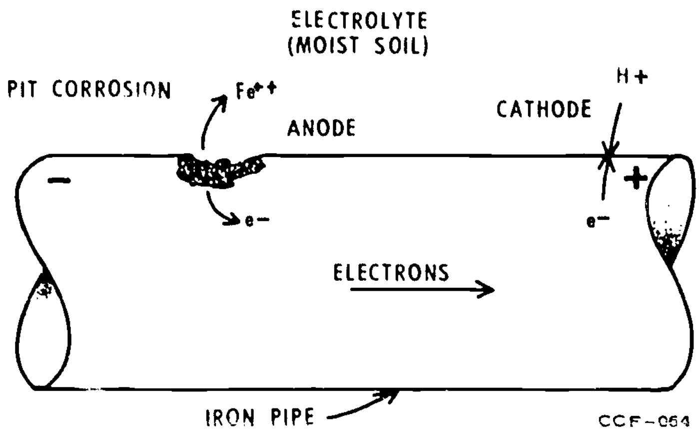


Figure 4–6. Simple corrosion cell caused by dissimilar environment.

Thus, there is no way other than by potential measurement in the exact location of the solution, to predict the potentials of the metals and the direction of a galvanic effect in that location.

The situation, however is not quite as bad as it seems. Metals will corrode about the same in most of the locations they are likely to be used. Thus, their positions in the galvanic series may be about the same in most locations. Observations of potentials and galvanic behavior are generally made in sea water. Metals are arranged in a galvanic series based on these observations. In the absence of data more directly applicable to other locations, an estimate is made of the probable direction of the galvanic effects. You may be requested to take metal-to-metal readings where data more directly applicable to a certain location are needed.

In dissimilar metal couplings, the more active metals in the galvanic series will corrode to protect the more noble metals. It is inconvenient to compare the potentials of different metals to each other by measuring all sorts of combinations. "Bench marks" can be provided for potential measurements to which any measured potential may be compared.

Although there are several potential "bench marks" in common use, all of them are related to a basic standard. One-half of the cell which generates the potential that is measured is represented by a platinized platinum electrode over which hydrogen gas is bubbled while immersed in a solution having a definite concentration of hydrogen ions (expressed as an activity of one). Using such an electrode as one-half of a galvanic cell and immersing pure metals in solutions having a concentration of their ions at an activity of one, a series of voltage measurements can be made. If the potential of the platinized platinum electrode covered with hydrogen in its standard solution is said to be zero on our scale of potentials, then we can describe the potentials of all the other metals in their appropriate solutions in terms of the voltage that is generated in the cells. The electromotive force (emf) series (table 4-2) shows the relative tendency of metals to corrode when coupled in a given location. With hydrogen as the reference point, all less noble metals will have a negative (−) potential, and all more noble metals will have a positive (+) potential. In measuring and reporting potentials, it is necessary to indicate the magnitude (amount) of the voltage and its sign (+ or −). The minus sign indicates that the metal is negative with respect to the reference electrode.

Inspection of the galvanic cell suggests that corrosion damage at the anode should be directly proportional to the potential difference between the two metals and inversely proportional to the circuit resistance. Metals having widely different open-circuit (single electrode or corrosion) potentials in a given location would be expected to generate

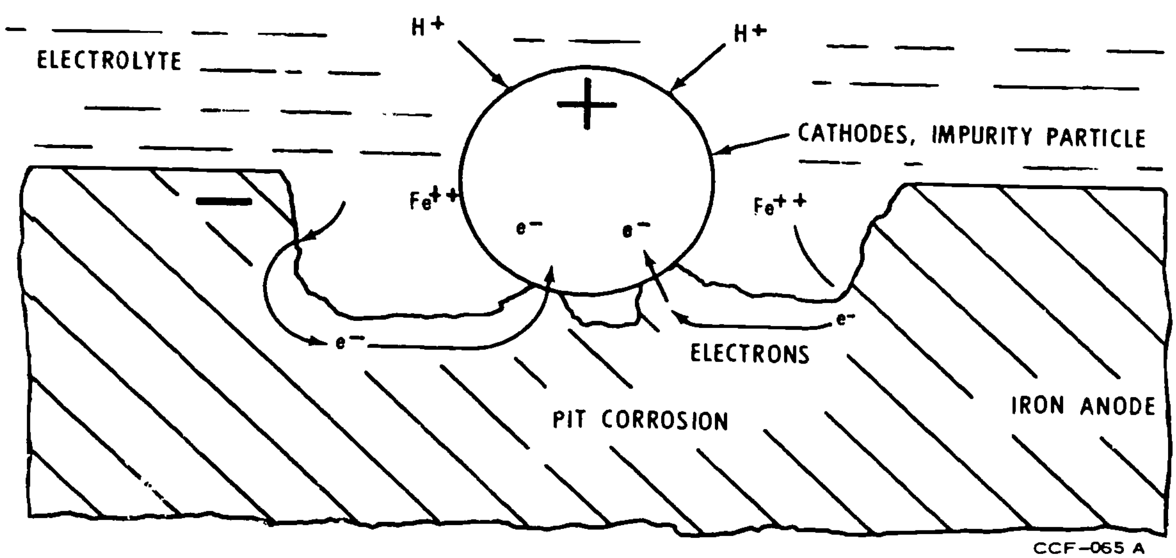


Figure 4–7. Simple corrosion cell caused by impurities in metal.

TABLE 4-1
GALVANIC SERIES

| ANODIC OR CORRODED END OF THE SERIES |
| --- |
| Magnesium (Galvomag alloy) |
| Magnesium (H-1 alloy) |
| Zinc |
| Aluminum (Alclad 3003) |
| Aluminum (3003 - H18) |
| Aluminum (6061 - T6) |
| Aluminum (5052 - H38) |
| Cast Iron |
| Carbon Steel |
| Stainless Steel Type 430, 17% Cr (active) |
| Ni-resist cast iron, 20% Ni |
| Stainless Steel Type 304, 18% Cr, 8% Ni (active) |
| Stainless Steel Type 410, 13% Cr (active) |
| Ni-resist cast iron, 30% Ni |
| Ni-resist cast iron, 30% Ni + Cu |
| Naval Rolled Brass |
| Yellow Brass |
| Copper |
| Red Brass |
| Composition G Bronze |
| Admiralty Brass |
| 90-10 Cupro-nickel, 0.8% iron |
| 70-30 Cupro-nickel, 0.06% iron |
| 70-30 Cupro-nickel, 0.47% iron |
| Stainless Steel Type 430, 17% Cr (passive) |
| Nickel |
| Stainless Steel Type 316, 18% Cr, 12% Ni, 3% Mo (active) |
| Inconel |
| Stainless Steel type 410, 13% Cr (passive) |
| Titanium (commercial) |
| Silver |
| Titanium (high purity from iodide) |
| Stainless Steel Type 304, 18% Cr, 8% Ni (passive) |
| Hastelloy C |
| Monel |
| Stainless Steel Type 316, 18% Cr, 12% Ni, 3% Mo (passive) |
| CATHODIC OR PROTECTED END OF THE SERIES |

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TABLE 4–2
ELECTROMOTIVE FORCE (EMF) SERIES

| ELEMENTS | REFERENCE ION | POTENTIAL IN VOLTS |
|---|---|---|
| Lithium | $Li^+$ | -2.959 |
| Rubidium | $Rb^+$ | -2.925 |
| Potassium | $K^+$ | -2.924 |
| Calcium | $Ca^{++}$ | -2.7 |
| Sodium | $Na^+$ | -2.714 |
| Magnesium | $Mg^{++}$ | -2.340 |
| Zinc | $Zn^{++}$ | -0.761 |
| Chromium | $Cr^{++}$ | -0.71 |
| Chromium | $Cr^{+++}$ | -0.50 |
| Iron | $Fe^{++}$ | -0.44 |
| Cadmium | $Cd^{++}$ | -0.401 |
| Nickel | $Ni^{++}$ | -0.23 |
| Tin | $Sn^{++}$ | -0.13 |
| Lead | $Pb^{++}$ | -0.12 |
| Iron | $Fe^{+++}$ | -0.045 |
| Hydrogen (reference point) | $H^+$ | 0.000 |
| Copper | $Cu^{++}$ | +0.344 |
| Copper | $Cu^+$ | +0.522 |
| Silver | $Ag^+$ | +0.797 |
| Mercury | $Hg^{++}$ | +0.798 |
| Gold | $Au^{+++}$ | +1.3 |

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a larger galvanic current than those having a smaller difference. Similarly, it would appear that galvanic corrosion damage should increase with increasing conductivity of the environment. These statements are basically true, but it must be remembered that the galvanic current generally decreases with time because of polarization at the anode, the cathode, or both electrodes.

*Concentration-cell corrosion*. Electrochemical attack of a metal or alloy because of differences in the environment is called concentration-cell corrosion. At least five types of concentration cells exist. Of these, the differential-aeration or oxygen-concentration cell is the one generally responsible for corrosion of underground steel structures. Areas on a pipeline surface in contact with electrolyte having a high oxygen content are generally cathodic to those areas in contact with electrolyte having a lower oxygen content. This is understandable because, in neutral and alakline locations, regions of high oxygen content tend to be preferred cathodic sites where the reduction of oxygen can occur.

On cross-country underground pipelines, concentration-cell corrosion can occur over relatively long distances. This is caused by what are often referred to as long-line corrosion currents. For example, steel pipe exposed to loam generally will be cathodic to areas where the pipeline is in contact with clay, as shown in figure 4-8. Pipe buried under a river will be anodic to aerated soil adjacent to the stream.

Localized soil differences can also be involved in the concentration-cell corrosion of underground pipelines. For example, steel in contact with undisturbed low-oxygen-content soil will generally be anodic to steel in contact with the aerated backfill as shown in figure 4-9. Corrosion damage to the underside of the pipeline is accelerated by the large cathode-to-anode area ratio that exists. In the same way, steel in contact with lumps of clay will be anodic to nearby steel if the major backfill material is a sandy loam. Localized concentration-cell corrosion is believed to be a major cause of corrosion leaks in underground pipelines.

*Concentration-cell corrosion*. This is probably the most common cause of corrosion to the inside of steel storage tanks. Dirt, debris, sludge, and other solids which are on the tank bottoms will cause localized anodic dissolving when water is in the tank, as shown in figure 4-10. Rapid concentration-cell corrosion occurs under the solids because of the large cathode-to-anode area ratio. This causes large quantities of steel to be converted into solid corrosion products (rust) and dissolved ions. Dissolved metallic ions can contaminate certain grades of fuel. Also, solid corrosion products can be transported and deposited elsewhere in the system, where they can cause additional concentration-cell corrosion to occur. Eventually, the tanks leak. This results in loss of fuel, a safety hazard, expensive repairs, temporary unavailability of the product being stored, and leaking fuel contaminating underground and surface water supplies.

*Stray-current corrosion*. In addition to these "normal" forms of deterioration, stray-current corrosion (sometimes erroneously referred to as electrolytic corrosion) can also occur on an underground steel structure. This form of corrosion is related to uncontrolled direct currents flowing in the earth. The currents flow onto the underground steel structure at certain locations, causing no detrimental effect. Similarly, the currents cause no damage while they are flowing along the structure. Eventually, however, the currents must leave the structure, return to the earth, and flow to their source of generation. This area where currents leave the pipeline is where serious corrosion damage occurs. Stray-current corrosion and "normal" corrosion

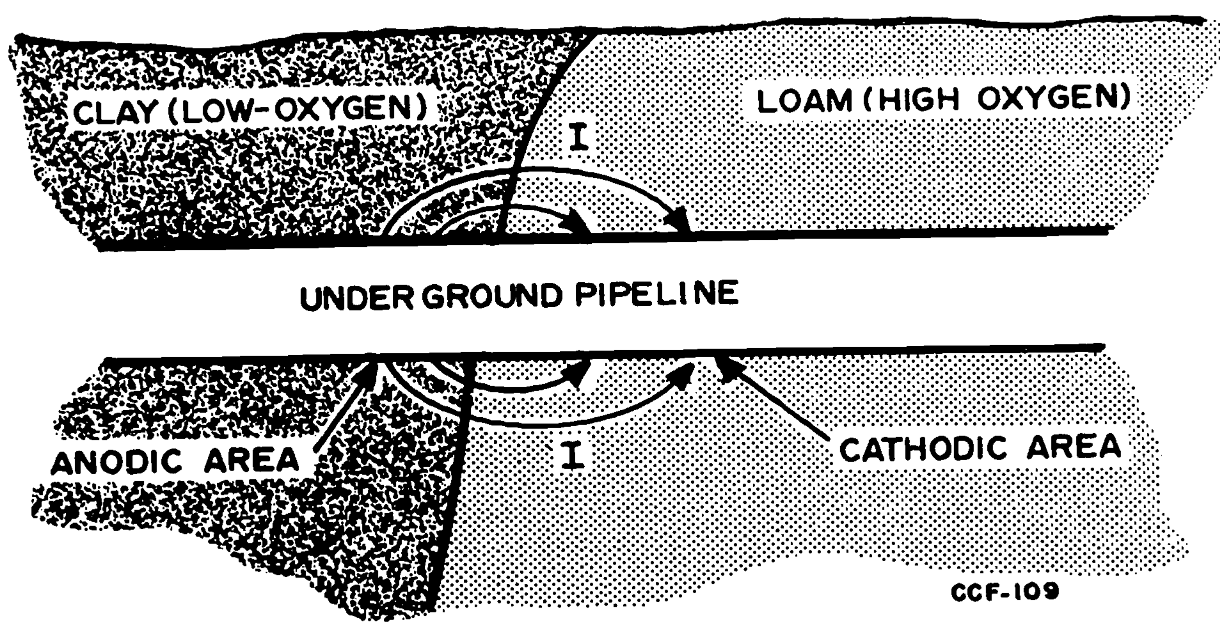


Figure 4–8. Long-line concentration-cell corrosion.

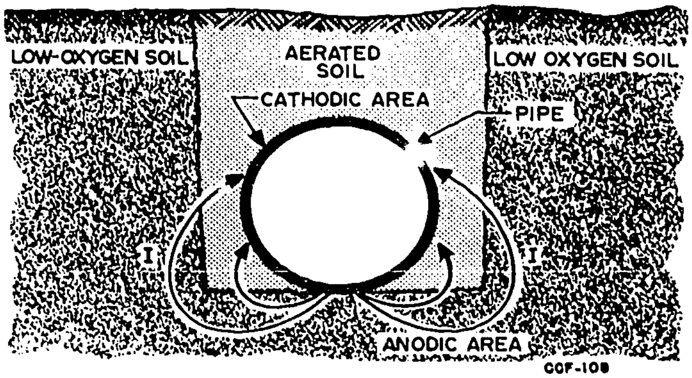


Figure 4–9. Localized concentration-cell corrosion.

activities are similar in that corrosion always occurs at the anodic areas. The basic difference between the two is that an external current causes stray-current corrosion, and the current is generated by the corrosion cell when "normal" corrosion activity takes place. Another difference is that the anode will be the positive electrode when stray-current corrosion is involved.

**Exercises (442):**

1. In what area does corrosion always occur?

2. In what type of corrosion is the anode the positive electrode?

3. The uniform anodic dissolving of metal over the entire exposed surface is what kind of corrosion?

4. What type of corrosion occurs if two dissimilar metals are connected together?

5. In a copper-to-aluminum connection, which metal is the anode and which metal is the cathode in the galvanic series?

6. Where are observations of potentials and galvanic behavior generally made?

7. What is the potential of a platinized platinum electrode covered with hydrogen in its standard solution?

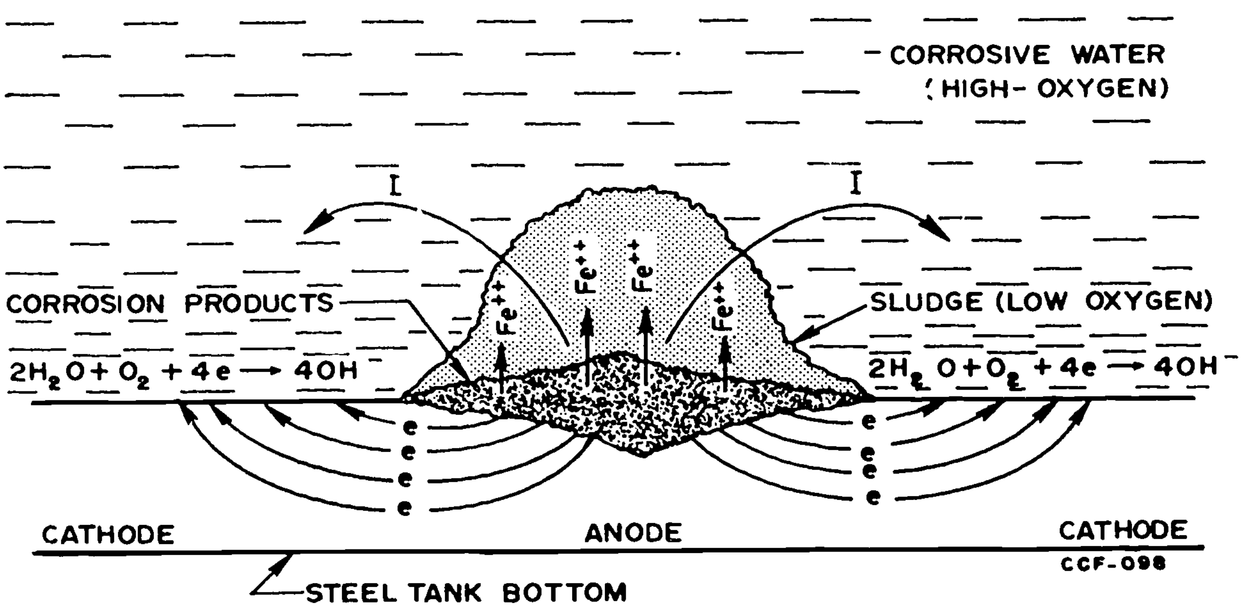


Figure 4–10. Concentration-cell corrosion under sludge or bottom of fuel storage tank.

8. What is used as the reference point in the emf series?

9. Why does the galvanic current decrease with time?

10. What type corrosion occurs by electrochemical attack of a metal because of differences in the environment?

11. In long-line corrosion, which is anodic, steel pipe exposed to loam or steel pipe exposed to clay?

12. What is a major cause of corrosion leaks in underground pipelines?

## 4-2. Cathodic Protection

Corrosion occurs naturally throughout the world. Although it can't be stopped, it can be controlled. In this section you will learn about two methods commonly used to control it.

**443. Explain how corrosion can be reduced and distinguish between galvanic anode systems and impressed current systems.**

Corrosion is reduced (mitigated) when the anodic (corrosive) current leaving the structure is reduced. Thus, corrosion should cease when the anode current reaches zero. Examination of the corrosion cell and application of Ohm's Law suggest that there are two ways of doing this. One is to make the circuit resistance infinitely large, and the other is to reduce the potential difference between the cathodic and anodic sites to a very small value. Cathodic protection is the corrosion control technique that minimizes the anode dissolving by reducing the potential difference between the cathodic and anodic sites.

Basically, cathodic protection is an electrical method of reducing (mitigating) corrosion on structures that are exposed to electrolytes such as soils and waters. Corrosion control is achieved by forcing a proper amount of direct current to flow from auxiliary anodes, through the electrolyte, and onto the structure to be protected. Thus, corrosion of a structure is eliminated when the open-circuit potentials of the cathodic sites are polarized to the open-circuit potentials of the anodic sites. The entire structure becomes cathodic relative to the auxiliary anodes.

**Methods of Cathodic Protection.** There are two basic methods of corrosion control by cathodic protection. One is the use of current that is produced when two electrochemically-dissimilar metals/alloys are metallically connected and exposed to the electrolyte. This is commonly referred to as the galvanic anode type of cathodic protection system. The other technique is the use of a direct current power source and auxiliary anodes. This is commonly referred to as an impressed current type of cathodic protection system. Since the power source is almost always a rectifier unit, this type of system is sometimes referred to as a rectifier type cathodic protection system.

Both types of cathodic protection systems are used to protect underground steel pipelines and storage tanks. The advantages and limitations of each must be considered before a cathodic protection system is selected, designed, and installed.

*Galvanic anode systems.* The galvanic anode system provides cathodic current by galvanic corrosion. The current is generated by metallically connecting the structure to be protected (the cathode) to a metal/alloy nearer the active end of the galvanic series (the anode). Since the anode is specifically chosen to corrode away in place of the protected structure, this system is also known as the *sacrificial anode system*. As in any electrochemical cell, both the structure and the anode must be in contact with the electrolyte (in this case, the soil) and must be connected electrically through a metallic conductor, as shown in figure 4-11. Occasionally, circumstances require the limiting of current flow to the protected structure, as in the case of aluminum. Where this occurs, place a resistor wire made of nichrome in the circuit between the anode lead and structure lead. Also, resistance may be used to extend the life of the anodes, by limiting the current, while achieving adequate protection. The basic components of a single, galvanic anode installation, as shown in figure 4-12, are: the structure to be protected, the anode (with or without a special backfill), and an insulated lead wire connecting the structure to the anode.

The galvanic anode system has certain advantages and limitations as outlined in table 4-3. Basically, a galvanic anode system is used where small amounts of current are needed and where the electrolyte resistivity is sufficiently low that the current required can be obtained with a reasonable number of anodes. Galvanic anodes are also used to supplement impressed current systems and to correct certain stray-current corrosion conditions.

The anode system requires very little maintenance because it has no power source and requires no regulation. Anodes for the galvanic anode system may be magnesium, zinc, or aluminum alloy. In practice, however, only high-purity zinc and alloys of magnesium are used for protection of steel in soils and fresh waters. Aluminum alloys are not used in these locations because the surface film that forms on the anode tends to reduce the current output. Aluminum alloys are used to protect steel in sea water and other salty locations. Anode life varies from 5 to 30 years, depending upon the type of anode used. It is conservative to figure that about 17 pounds of magnesium or 26 pounds of zinc are wasted away by electrolysis from an anode per ampere year. Commercially available aluminum anodes are not over 75 percent efficient and are consumed at a rate of 9

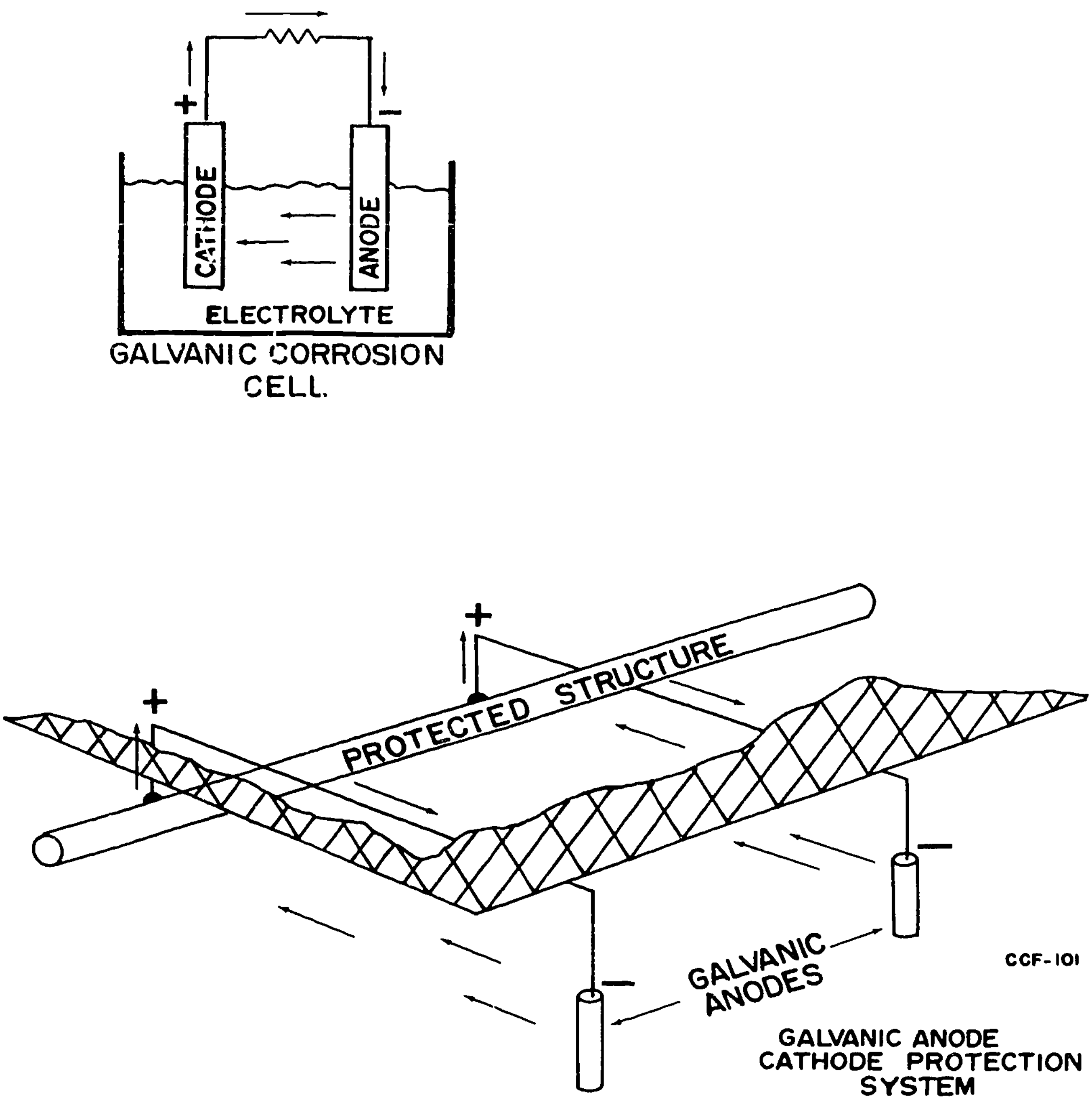


Figure 4–11. Comparison between galvanic cell and galvanic anode systems.

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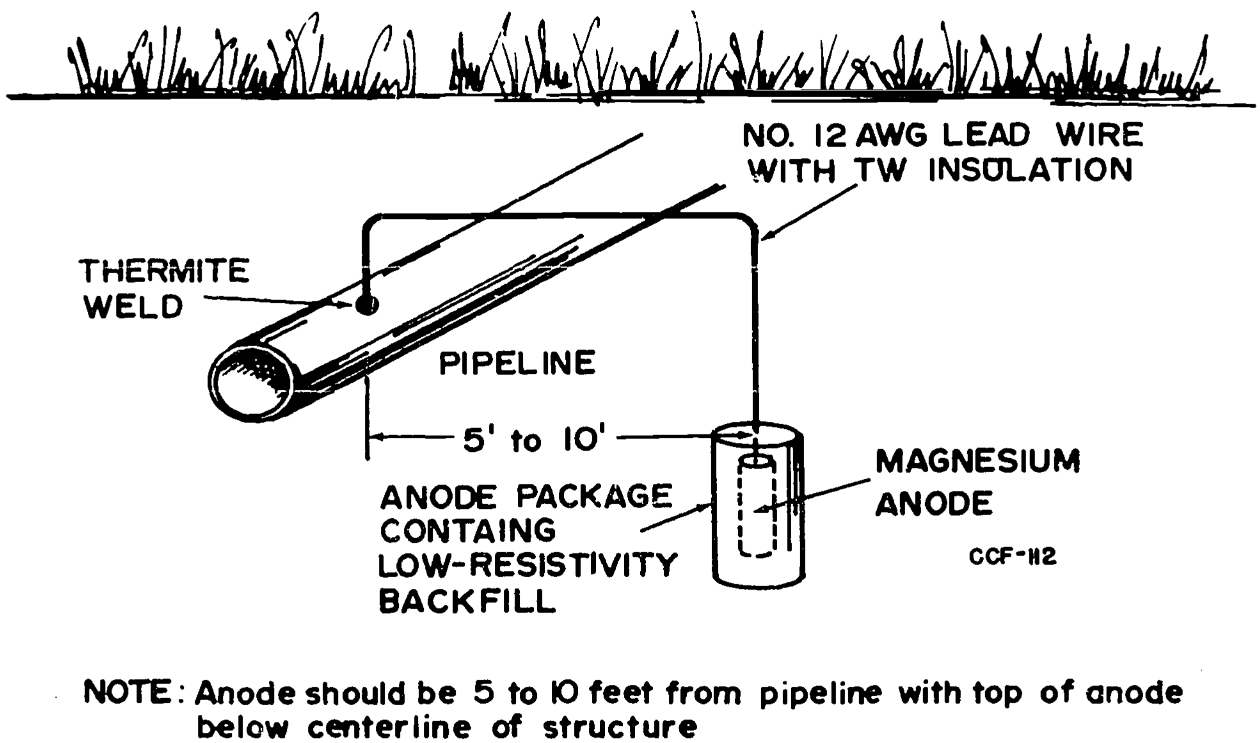


Figure 4–12. Sacrificial anode type cathodic protection.

pounds per ampere year. This high consumption rate is undesirable; therefore, magnesium and zinc are used most often.

Magnesium anodes are obtained in either the standard alloy or a special high manganese alloy. Although the rates of metal loss are similar for both materials, the standard alloy anode produces a voltage of about 0.70 volt with a buried iron or steel cathode while the high manganese alloy anode will produce a voltage of about 0.90 volt with the same cathode. This means that an anode of one alloy cannot be used as a direct replacement for an anode of the other alloy, unless an adjustment is made in the external circuit resistance.

Replacing a standard anode with a high manganese anode raises the galvanic cell potential by about 28 percent and according to Ohm's law, the current flow changes in the same proportion. Since the rate of metal loss varies directly with the current flow, the anode life is reduced by 28 percent.

The same principles apply when you replace a high manganese anode with a standard anode. Because the voltage is lower by 28 percent, the life of the anode is increased 28 percent. However, in this case the amount of electrical protection is reduced because (again per Ohm's law) the lower voltage reduces the current proportionately.

Zinc anodes were the earliest sacrificial anodes used in cathodic protection systems, and they are still in widespread use today. These anodes are available in various shapes and sizes and in two alloys, one for soil and fresh water electrolytes, and one for a sea water electrolyte.

The practical electrochemical equivalent of zinc is about 26 pounds per ampere year. Current density considerations usually require that zinc anodes be relatively long and slender so that they will extend through varying layers in soil electrolytes. Although the overall rate of metal loss is fairly constant, these electrolytic variations cause uneven deterioration of the anode and sometimes anode failure. Standard anodes have iron cores to provide electrical continuity even if part of the anode is completely eaten away and the metal loss can be made somewhat more uniform by chemical backfill used around each anode. Backfill around zinc anodes must be hand placed because prepackaged units are not available for zinc.

*Impressed current systems.* An impressed current system provides cathodic current from an external power source. A DC power source forces current to discharge from expendable anodes, to the electrolyte, and onto the structure to be protected. Although the current is not generated by the corrosion of a sacrificial metal/alloy, the energized materials used for the auxiliary anodes do corrode. As in any electrolytic cell, both the structure and the anode must be in contact with the electrolyte (in this case, the soil) and must be connected electrically through an insulated wire circuit, as shown in figure 4-13.

The basic components of an impressed current system, as shown in figure 4-14, are the structure to be protected, a DC

TABLE 4-3
ADVANTAGES/LIMITATIONS OF SACRIFICIAL ANODE SYSTEMS

**ADVANTAGES**

- No External Power Required
- No Regulation Required
- Easy to Install
- Minimum of Cathodic Interference
- Anodes Can be Readily Added
- Minimum of Maintenance
- Uniform Distribution of Current
- Installation Can be Inexpensive*
- Minimum Right-of-Way/Easement Costs
- Efficient Use of Protective Current

**LIMITATIONS**

- Limited Driving Potential
- Lower/Limited Current Output
- Installation Can be Expensive**
- Poorly-Coated Structures Require Many Anodes
- Can be Ineffective in High-Resistivity Environments

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*Installation of anodes at time of construction.
**Installation of anodes after con'truction.

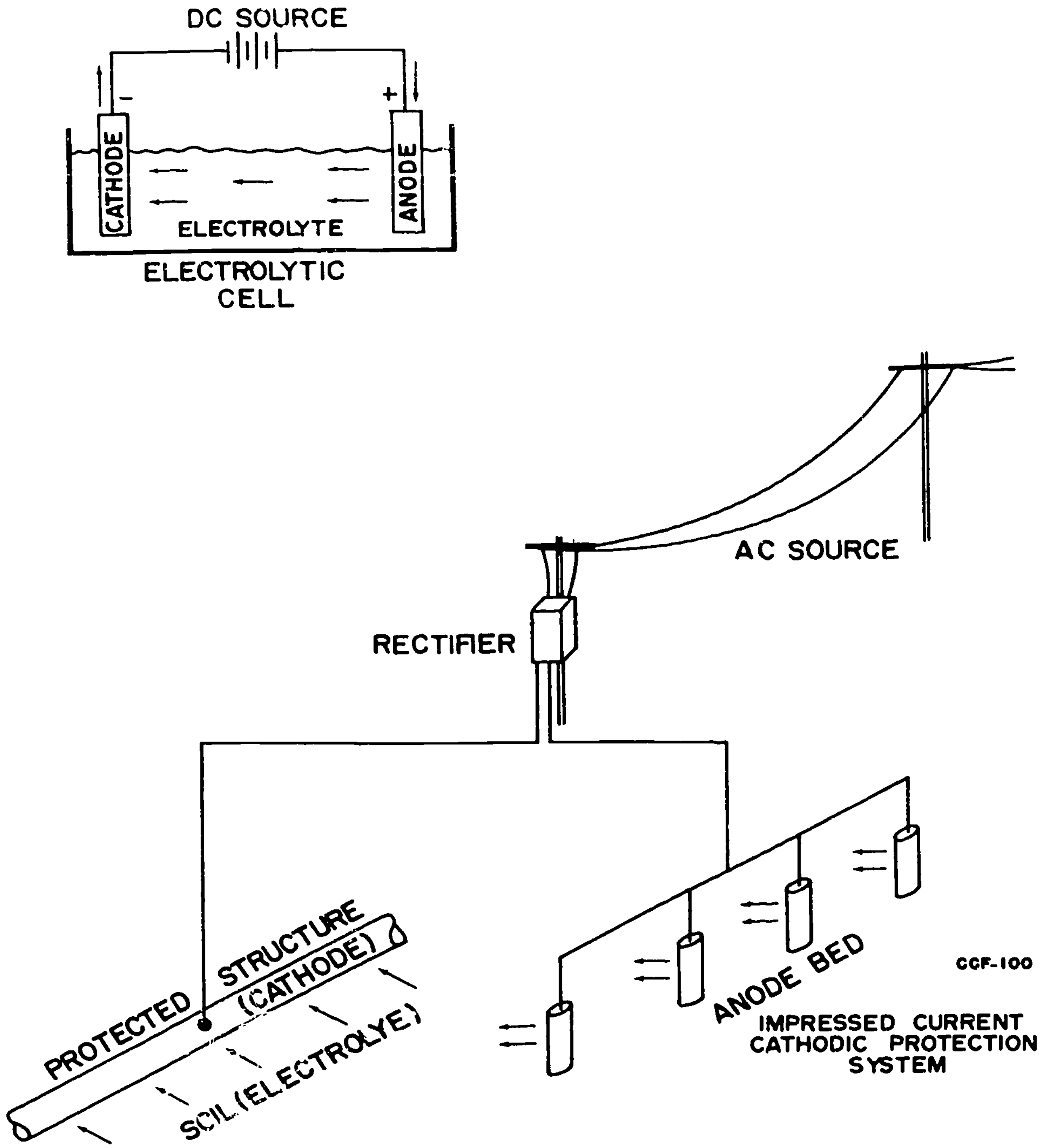


Figure 4–13. Impressed current protection systems.

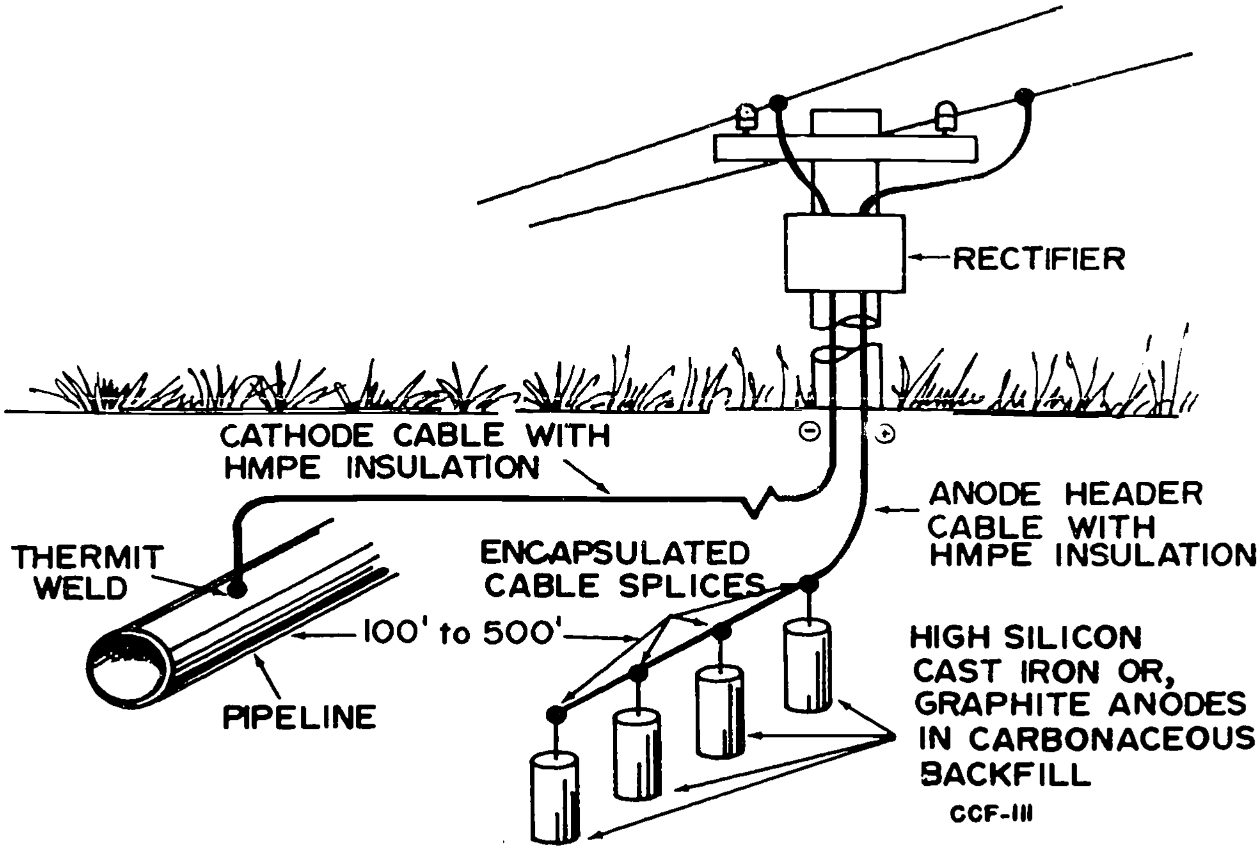


Figure 4–14. Impressed current installation for an underground steel pipeline.

power source, a group of auxiliary anodes (groundbed, or anode bed) with or without a carbonaceous backfill, and insulated lead wires connecting the structure to be protected to the negative terminal and the groundbed to the positive terminal of the power source.

The DC power source is usually a rectifier unit. Direct current can also be obtained using engine-driven generators, batteries, wind-powered generators, thermoelectric generators, solar cells, and fuel cells. The major components of a cathodic protection rectifier include a circuit breaker to protect the system components, a step-down transformer to reduce the AC voltage, coarse and fine tap adjustments, the rectifier stack to convert AC to DC, and instruments to measure the DC voltage and current output. See figure 4-15 for a schematic of the basic components. You will notice that the two main electrical components in this system are the transformer and the rectifier. The transformer steps down line voltage to a value of 12 to 40 volts, while the rectifier changes alternating current to direct current. The amount of current flow can be controlled by changing the taps on the secondary side of the transformer. The rectifier stack can be either silicon or selenium. Although silicon stacks do not age as rapidly as selenium, they are susceptible to failure by voltage/current overload. Selenium stack rectifiers are widely used for cathodic protection systems, probably because they are less susceptible to this transient voltage/current overload. For large cathodic protection current requirements, however, silicon stacks are often specified because of their higher AC to DC conversion efficiencies.

The impressed current type of cathodic protection system has certain advantages and limitations. These are listed in table 4-4. The impressed current system is the most practical when extensive installations must be protected, the current requirements are large, and the average soil resistivity is high. A unique advantage of the impressed current system is the ability to protect a large surface area with a single groundbed/rectifier installation. Furthermore, since the voltage and current output can be adjusted, the system has operational flexibility. This system, however, must be carefully designed and installed. Otherwise, stray-current corrosion of other structures in the area can be a problem.

**Types of Impressed Current Anodes.** The anodes of an impressed current system provide the means for the protective current to enter the electrolyte. Since the anodes form the corroding part of the system, the best material is usually one which has a low rate of weight loss per ampere-year. The most commonly used material for impressed current anodes are graphite and high silicon cast iron. Aluminum is sometimes used in water storage tanks where it is convenient to install, has a low first cost, and ice

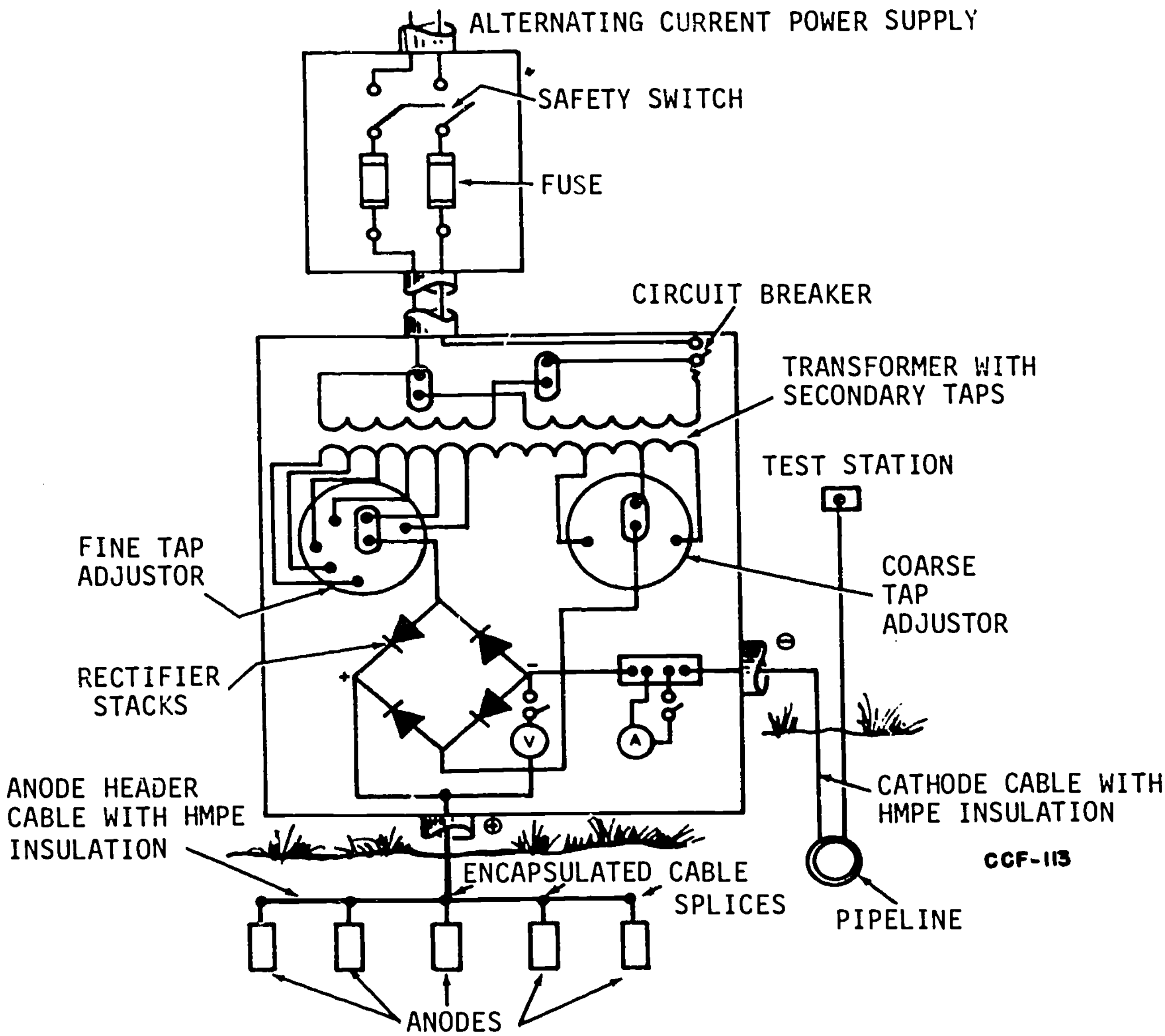


Figure 4–15. Schematic view of an impressed current system showing the basic components of the rectifier.

damage is likely. In areas where heavy icing is not a problem, high silicon cast-iron anodes should be used in lieu of aluminum for lower long-term cost. Platinum-coated titanium or niobium anodes are being used more as impressed current anode material. Scrap iron and steel can also be used for anodes in this system. Consumption rates for platinum-coated titanium and niobium, high silicon cast iron, graphite, aluminum, and steel/iron are, respectively 0.00001 (in sea water), less than 1, 2, 4, 3, 9, and 20 to 22 pounds per ampere year. Iron and steel are being used progressively less for auxiliary anodes because of the high consumption rates and the desire of pipeline operators to have long-life expectancy groundbeds.

*Graphite anodes*. Graphite anodes usually have the shape of a simple cylinder. One popular size of anode is 3 inches in diameter and 60 inches long. Anodes are furnished with a No. 8, 7-strand, high molecular weight polyethylene (HMPE) insulated lead wire. It is important that the lead wire-to-anode connection is properly sealed. Many graphite-anode groundbeds have failed because this factor was neglected. The inherent brittleness of graphite also requires that the anodes be handled with care.

*High silicon cast iron anodes*. A wide variety of high silicon cast iron anode shapes and configurations are available. For the protection of underground steel structures, anodes having the shape of a simple cylinder are

TABLE 4-4
ADVANTAGES/LIMITATONS OF IMPRESSED CURRENT SYSTEMS

ADVANTAGES

- Can be Designed for Wide Range of Voltage and Current
- High Ampere Year Output Available from Single Groundbed
- Large Areas Can be Protected by Single Installation
- Variable Voltage and Current Output
- Applicable in High-Resistivity Environments
- Effective in Protecting Uncoated and Poorly-Coated Structures

LIMITATIONS

- Can Cause Cathodic Interference Problems
- Subject to Power Failure and Vandalism
- Requires Periodic Inspection and Maintenance
- Requires External Power
- Monthly Power Costs
- Overprotection Can Cause Coating Damage

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used. One end of the anode is usually enlarged in order to provide a reliable attachment of the lead wire. Popular anode sizes are 1.5 to 3-inches in diameter and 60 inches long. Anodes are usually furnished with a No. 8, 7-strand, HMPE insulated lead wire. The anode-to-lead wire connection must be properly sealed. The moisture seal should include epoxy-resin encapsulation. It should also be noted that high silicon cast iron is somewhat brittle. The anodes should be handled with care.

*Aluminum anodes*. Aluminum, when used as an impressed current anode, is usually in the form of a rod 1/2-inch to 3-inches in diameter. Aluminum anodes are generally used only where a 1-year or so life is required (icing conditions in unheated tanks, etc). In addition, alloying is extremely critical, making this material impractical for most applications.

*Platinum wire anodes*. Platinum wire is sometimes used as an anode, generally to protect internal surfaces where space is limited (internal surfaces of pumps, pipelines, wells, etc.). Platinum is essentially insoluble. However, this metal is fragile and prohibitively expensive, and is used mainly as a thin coating over other noble metals.

*Platinitized titanium anodes*. Plantinitized titanium (tantalum, niobium) anodes are also available. Titanium is a highly reactive metal which forms an adherent, inert oxide film in most corroding media. Very little current will leave this surface, once the oxide has formed, because the oxide has high electrical resistance. This eliminates the use

of titanium itself as an anode. However, if a thin layer of platinum is plated onto titanium (platinized titanium), current flows from the titanium through the platinum into the electrolyte. Platinized titanium anodes are easily fabricated and operate at high current densities. Only a very small platinized area is, therefore, required for most applications. Fully platinized and partially platinized anodes are both manufactured. The partially platinized anodes allow current flow only from platinized areas. These anodes are stronger and less expensive than solid platinum. Anodes that are fully platinized can withstand extremely high voltages. However, those which are only partially platinized are subject to voltage limitation (breakdown voltage). The breakdown voltage is that at which titanium oxide decomposes. This value varies from 8.5 to 14 volts anode-to-electrolyte voltage, depending on electrolyte, film thickness, surface roughness, and salinity of water. A system voltage of 12 volts is generally permissible.

**Installing Anodes.** The wiring used to make connections between the anodes and the structures to be protected must be resistant to the electrolytic action of the soil. Bury the wire to a depth of 2 feet or deep enough to avoid damage by cultivation or erosion. Install plastic warning tape in the ditch above the lead wires. Locate the warning tape six to eight inches below the surface. The warning tape replaces the wooden board as a protective warning for direct buried lead wires.

Connect anodes in the groundbed to the positive terminal of the rectifier with an adequately sized HMPE-insulated header cable for impressed current system. Securely attach the anode lead wires to the header cable. Split-bolt connectors are commonly used to obtain permanent, low-resistance connections. All splices/connections to the anode header cable must be perfectly sealed to prevent moisture penetration and subsequent loss of the groundbed. This is best achieved using commercially available splice kits in which impermeable seals are obtained by casting a two-package epoxy resin around the electrical connection.

The HMPE-insulated cable used to connect the negative terminal of the rectifier to the underground steel structure must also be adequately sized. This cable should be thermite welded to the structure. The thermite weld area should be properly coated if the underground structure is coated.

**Backfill.** When an impressed current system is used to reduce corrosion on an underground steel structure, the auxiliary anodes are often surrounded by a carbonaceous backfill. Backfill materials commonly used include coal coke breeze, calcined petroleum coke breeze, and natural graphite particles. This backfill performs the following important functions:

*a*. Lowers anode-to-soil resistance.
*b*. Eliminates gas blocking—maintains uniform low resistance.
*c*. Permits use of higher currents.
*d*. Eliminates high-drain points and resulting selective attack on anodes.
*e*. Greatly extends life of groundbeds.

The carbonaceous backfill, however, cannot be expected to increase the groundbed life expectancy unless it is well compacted around the anodes. You can install backfill in three ways: in dry form, as a slurry, or as part of a prepackaged unit in which the anode is completely surrounded by the backfill material. Impressed current anodes are also available packaged in metal stovepipelike cans, but are not recommended for Air Force use except in swampy or hard-to-install areas, because of higher cost and the fact that the lead-to-anode connection or the anode itself cannot be inspected for breaks. Backfill should extend at least 12 inches from each end of the anode and should surround the anode to a thickness of at least 3 to 4 inches.

For underground applications in galvanic anode systems, both high-purity zinc and magnesium-alloy anodes are normally surrounded/packaged with a special backfill to provide a uniform environment around the anode. This backfill has the following advantages:

*a*. Allows uniform deterioration of the anode material.
*b*. Provides a low resistance path to earth.
*c*. Allows greater current flows.
*d*. Reduces gas-film formation on the anode surface.
*e*. Extends anode life.

Several materials are used for backfill, depending on the particular situation. Backfill for zinc or magnesium anodes is usually a gypsum-bentonite mixture. In low resistivity soils, a 50–50 mix can be used. In higher resistivity soils, the standard proportions are 75 percent gypsum and 20 percent bentonite with 5 percent sodium sulfate added. Gypsum molding plaster has been used to make a precast package with the anode in the center of a molded unit.

**Exercises (443):**

1. How can corrosion be reduced? What is this process called?

2. What type current is used in cathodic protection?

3. Identify the statements below as pertaining to galvanic anode (GA) systems or to impressed current (IC) systems by placing the appropriate initials in the space provided. Statements may apply to one or to both.

_____ a. Two dissimilar metals connected together by a conductor and exposed to an electrolyte.
_____ b. A direct current power source and auxiliary anodes are used.
_____ c. The cathode and the anode must be in contact with the electrolyte.
_____ d. To limit the current, place nichrome wire in the circuit between the anode and the cathode.
_____ e. Voltage and current output can be varied.
_____ f. The basic components are the structure, anode, and an insulated lead wire.

_____ g. The basic components are the structure, a DC power source, anodes, and insulated lead wires.
_____ h. Used where small amounts of current are needed.
_____ i. Has a wider range of voltage and current.
_____ j. Anodes of magnesium, zinc, or aluminum alloy are used.
_____ k. Graphite and high silicon cast iron are the most common anodes.
_____ l. Aluminum alloys are used to protect steel in sea water.
_____ m. Change the external resistance when replacing one type anode with another type.
_____ n. Wire should be buried 2 feet deep.
_____ o. Plastic warning tape is placed above the lead wires.
_____ p. Test stations are provided to determine the system's effectiveness.
_____ q. Requires less maintenance of the two.
_____ r. Protects a greater area.
_____ s. To protect internal surfaces of pumps, a platinum wire is used.
_____ t. The lead wire is attached to the structure by thermite weld.
_____ u. Backfill is used to extend the life of groundbeds.
_____ v. Backfill should surround the anodes by at least 3 to 4 inches.

## 4-3. Inspection and Maintenance

The ability of cathodic protection equipment to perform its functions, or to continue to perform its function for its normal life cycle, must be determined if to operate dependably and economically. A continuous inspection program of testing, measuring, and analyzing must be used to obtain this objective. Properly maintained equipment will increase the lifespan of a cathodic protection system. This section describes the methods and procedures used to inspect and maintain cathodic protection systems.

**444. State the maintenance requirements for cathodic protection systems.**

**Maintenance.** The impressed current system requires considerably more maintenance than the galvanic anode system, because a direct current operates the system. By far the most widely used and cheapest source of DC is from the transformer-rectifier set. When alternating current from a commercial source is not available, then batteries, engine-driven generator sets, and wind-driven generators must be used.

*Equipment in the system.* You must maintain all electrical equipment in compliance with the written instructions of the manufacturer and with standard operating procedures adopted by your base. All electrical work should be done with the rectifier safety switch in the off position.

Equipment, such as switches, rectifiers, and test stations, should be protected from the elements by metal inclosures which should be kept painted. Identification of the equipment is important for maintenance and record purposes. Maintain the rectifier to permit free air circulation around it for cooling. Keep air-cooled rectifiers free of dust, brush, and grass. The units should be inclosed to prevent the nesting of birds. Also, since these rectifiers give off some heat, they may attract snakes in isolated areas; therefore, be careful when you are making inspections or repairs. Keep oil rectifiers filled to the proper level and change the oil when it becomes cloudy. Make the wire connections above the oil level to prevent "wicking" the oil from the unit.

Check the insulation on existing current-carrying lines and, if deterioration is evident, replace the wires. Also check any overhead lines to see that they are securely fastened to the poles and that all connections are tight. Buried cables should be identified and marked on the utility plans to prevent accidental severing or damage.

*Pitting of structures.* Pit depth measurements are important in corrosion testing. If the corrosion is active in the pits, as determined by visual inspection, an approximation of the rate of penetration per year can be obtained. Corrosion does not usually proceed at a uniform rate; its rate either increases or decreases with time. Consequently, penetration rates obtained by spot checks are not always reliable when they are projected on a straight line basis. If the pits are heavily covered with a tight rust scale and are dry beneath the scale, this condition usually indicates that the pits have become sealed off and the corrosion has stopped or slowed down. If, however, the pits are covered with moist tubercles, or are wet and show bright metal when brushed out, this condition means that corrosion is active. Make your examination soon after excavation, because exposure to the air can dry out the pits and make them appear inactive, particularly if black iron oxide is allowed to change to a red iron oxide by increased oxygen.

About every 2 years, the structure should be checked for depth of pitting, and accurate records should be kept on these pits. Before you measure the depth of pitting on a structure, clean the surface of rust and scale. Usually, four pits are selected for measuring with a depth gage. The average of these pits will be the average penetration. This information should be recorded so that the amount of penetration per year over a period of years can be calculated.

*Protective coating.* Protective coating prevents corrosion by physically separating a metal structure from the electrolyte or corrosive environment. In this respect, protective coating directly influences the need for, and effectiveness of, cathodic protection systems. In theory, if a structure could be completely covered with an electrically insulating coating, there would be no current flow between the structure and the electrolyte, and no corrosion would occur. In practice, such an ideal situation is impossible to achieve, but it is possible to provide a great degree of corrosion protection through the use of a protective coating.

Coated structures fall into two broad classifications, buried structures (usually pipes) and immersed structures

(such as tank interiors, condenser pans, etc). Buried structures are usually covered with a built-up type of coating made by impregnating a wrapper material. A common example is a fiberglass pipe wrapper impregnated with bituminous binder. This type of coating is resistant to both moisture and physical damage. Immersed structures are usually painted. Many different types of paint are now available, including those with bituminous, rubber, epoxy, and vinyl bases.

It is apparent that a good continuous and unbroken coating reduces overall corrosion. What is not so apparent, but is still true, is that when coatings are damaged, corrosion accelerates at the bare spots. The rate of corrosion depends on the current density over the surface of the metal. The electric current will concentrate at small areas of bare metal and cause pitting, which in turn can cause early failure of the structure.

Coatings also age, becoming less effective as electrical insulators as they become older. As the coating loses its insulating properties, it allows current to flow out of the surface of the structure and corrosion takes place under the coating film. For this reason, as the coating gets older, the amount of current required to provide adequate protection becomes greater. It is important that a coating be carefully applied, be as continuous as possible, and that any breaks in it be carefully repaired before the structure is placed in service. During the life of the structure, any breaks in its protective coating should be repaired.

**Exercises (444):**

1. How should air-cooled rectifiers be maintained to permit free air circulation?

2. Why should rectifier units be inclosed?

3. When should the oil in oil-filled rectifiers be changed?

4. What do heavily covered pits with a tight rust scale and dry beneath the scale indicate?

5. What do pits covered with moist tubercles or are wet and show bright metal when brushed out indicate?

6. How does protective coating aid in corrosion control?

7. Where might the corrosion process be accelerated and for what reason on coated surfaces?

**445. Specify the requirements for cathodic protection records and associate the correct AF Form to given information.**

**Equipment Maintenance Program Records.** The success and effectiveness of a cathodic protection program depend on periodic servicing of installed systems. Corrosion control by cathodic protection can be highly effective when maintained adequately. The operation of cathodic protection systems requires that certain records be kept and reports made. These records, when taken together, provide a history of the cathodic protection system telling what was installed, when it was installed, where it was installed, and what care has been given the system, and whether or not the system is doing its job.

Develop and maintain maintenance action sheets and equipment maintenance records in accordance with AFR 85–1, *Resources and Work Force Management*. The maintenance action sheet allows time to perform the testing required on AF Forms 491 and 1686 for all installed cathodic protection systems. Maintain the various cathodic protection forms in the facility jacket folder for the cathodic protection system, category code 890–269. Establish a collection work order number (cost account code 580–86 for base and X7500 for housing) to include the following:

- Annual Performance Survey.
- Monthly Rectifier Checks.
- Annual Sacrificial Anode Checks.
- Maintenance of Rectifiers.
- Maintenance of Groundbeds.
- Maintenance of Sacrificial Anodes.
- Maintenance of Dielectric Fittings.
- Maintenance of Cathodic Protection for Water Heaters.
- Inspection of Leaks.

Establish a separate collection work order number (cost account code 13030) for the time expended by the engineer-manager.

*Comprehensive master plan*. TAB G–8 of the master plan, Cathodic Protection System, must show all installed rectifiers, groundbeds, and magnesium anodes. Reflect all changes in system design on TAB G–8. The corrosion engineer is responsible for updating this master plan as required. The corrosion engineer, also, must maintain a cathodic protection program record. The record must be in a tabulated form and must include the installed and proposed installation of cathodic protection systems. List an accurate description of all facilities protected under each project. If only a portion of a particular system is protected, list the percentage that is applicable. The "utility system protected" description must be in detail, including rectifier size and number of anodes.

*Technical records*. The corrosion engineer at each installation must maintain a file of technical records on each

installed cathodic protection system. These technical records must include, but not be limited to, such items as the Cathodic Protection Annual Performance Booklet, manufacturer's data on installed equipment, operating instructions, lists of repair parts, names and addresses of sources of parts and service, current price lists, repair and maintenance instructions, construction specifications, and shop drawings. Other items included are as-built drawings showing the location and extent of each cathodic protection system, any modification made during the life of the system, and the exact location of each rectifier, anode bed, and test station. Also, all underground utilities must be shown on a base layout mat (such as in TAB G–8 of the comprehensive master plan) and installed in the office of the corrosion engineer to delineate systems receiving cathodic protection. Mount the map or maps over a fibrous board or boards. Place a colored head pin at each point where a leak or failure is attributed to corrosion. Leave the pins in place for at least 5 years; use a different colored pin for each calendar year:

(1) If several leaks occur on the same system during a year in approximately the same location, use the same colored pin; however, note on the map the dates the leaks occurred.

(2) At the end of 5 years, it will be necessary to review and update these base maps. Maintain a file of old maps.

(3) Transfer the old map data to the new map so that a continuous history can be maintained. Delete the markings that are over 5 years old, if the map is crowded.

AF Form 491, Cathodic Protection Operating Log for Impressed Current System. This log must be kept on a monthly basis. The cathodic protection technician must make his entries in columns 10A through M every calendar month and verify that information recorded in block numbers 1 through 9 is correct. Every month submit the log to the corrosion engineer for evaluation. This monthly log includes the readings of four check, or test, points, the location of which must be given on AF Form 491. These test points must be selected each year from the annual performance survey. Some of the test points will remain the same from year to year, while others may change each year. Use AFM 85–5, *Maintenance and Operation of Cathodic Protection Systems*, for monthly readings on water storage tanks. Complete AF Form 491 in duplicate and maintain one copy in the cathodic protection facility jacket folder and the other copy in the Cathodic Protection Annual Performance Booklet. AFM 85–5 contains instructions for completing AF Form 491.

AF Form 1686, Cathodic Protection Operating Log for Sacrificial Anode System. This log is kept on a semiannual basis and entries in the log are made by the cathodic protection technician in columns 7A through H, making sure that all the basic information in blocks 1 through 6 is correct. Submit this log to the corrosion engineer for evaluation. Approximately 10 percent of all sacrificial anodes in a system must have test stations. Monitor each of these test stations using a separate log. Complete this log in duplicate, maintaining one copy in the cathodic protection facility jacket folder and the other copy in the Cathodic Protection Annual Performance Booklet. AFM 85–5 contains instructions for completing AF Form 1686.

AF Form 1687, Leak/Failure Data Records. The corrosion engineer or cathodic protection technician must inspect all leaks or failures and complete this form as required. The corrosion engineer is primarily responsible for performing inspections and records maintenance. In his absence the cathode protection technician must do these tasks and submit all copies of this form to the corrosion engineer for his review and further dissemination. One copy must be placed in the facility jacket folder, one copy must be included in the Cathodic Protection Annual Performance Booklet, and one copy must be forwarded to the major command. It should be forwarded immediately after completion of the form.

Before the excavation is backfilled, the corrosion engineer must decide whether to install sacrificial anode(s). If the piping system is protected by an impressed current system, the corrosion engineer must decide whether the rectifier current output is adequate or what adjustments are required. During the repair of corrosion leaks, it is desirable to make color photos of the failed structure. Color slides in sharp focus will be acceptable if color photographs cannot be made. Keep one slide of each leak at the base with the leak record and forward one to the major command.

AF Form 1688, Annual Cathodic Protection Performance Survey. AF Form 1688 is a survey worksheet to be used for the annual survey conducted by the base cathodic protection technician and engineer. The purpose of this survey is to check the total system and to show the degree to which the system is performing and meeting its intended purpose. Structure-to-soil potential measurements should be made at each building service line and at various other points along each distribution line that is protected by cathodic systems. The corrosion engineer must evaluate this data to determine the performance of the system. Using AFR 85–1 and the Annual Work Plan, this person must initiate changes, improvements, and/or readjustments wherever there are indications that parts of the system are not properly protected. Complete this form in duplicate. Maintain one copy in the cathodic protection facility jacket folder and the other copy in the Cathodic Protection Annual Performance Booklet. The major command corrosion engineer will review the survey data to determine if necessary or appropriate action has been taken by the base and to serve as the evaluation of the base's cathodic protection program.

In the maintenance of cathodic protection systems, you should refer frequently to AFM 85–5. Keep current with the information in this manual, including the periodic changes that are distributed.

*Data analysis*. The effectiveness of cathodic protection for corrosion control of underground steel structures can be established by leak record data analysis. The number of corrosion leaks that occur can be significantly reduced by cathodic protection.

Effective corrosion control by cathodic protection requires that the system be properly selected, designed, installed, and maintained. Adequate field test data must be collected and evaluated before a cathodic protection system is selected and designed. Otherwise, the cathodic protection system may not provide the desired corrosion control.

It cannot be overemphasized that existing/potential corrosion problems on underground steel structures must be properly identified before an attempt is made to correct them by the application of cathodic protection. For existing structures, this is generally accomplished by visual examination (bellhole inspection) of the structure and analysis of field test data.

Careful inspection is an important factor in cathodic protection maintenance. Performance after installation determines whether or not the systems are providing complete or only partial protection to a structure. You cannot be sure of a cathodic protection system until you inspect the completed system and collect accurate records of its performance.

A visual inspection of a metal structure usually reveals the effectiveness of the cathodic protection system. If a structure is found to be corroding, physical measurements on the structure must be taken. These are made on both aboveground and underground structures. Visual inspections usually reveal the following information:

- Whether the metal is corroding at the location expected.
- If the corrosion is active.
- What is the type of corrosion.
- What caused the corrosion.

Structure-to-electrolyte potential surveys are mandatory, and these should be supplemented with pipeline current tests. Adequate electrolyte resistivity data are required for the design of a cathodic protection system. In addition, tests must be conducted in order to establish the amount of current required for protection. For coated pipelines, tests must also be conducted in order to obtain a meaningful evaluation of the effective coating resistance. Field testing must be properly conducted. Effective cathodic protection systems usually cannot be designed by assumptions and guesswork.

**Exercises (445):**

1. What information is provided on cathodic protection system records?

2. Where are the records maintained?

3. Where are changes in system design kept?

4. Where are the technical records on each installed cathodic protection system kept?

5. How are leaks caused by corrosion in a base pipeline system recorded?

6. Match the correct form in column B with the function or procedure in column A.

| *Column A* | *Column B* |
|---|---|
| ______(1) Completed as required. | a. AF Form 491. |
| ______(2) Completed monthly. | b. AF Form 1686. |
| ______(3) Completed semiannually. | c. AF Form 1687. |
| ______(4) Completed annually. | d. AF Form 1688. |
| ______(5) Used to check performance of the entire system. | |
| ______(6) Used for sacrificial anode systems. | |
| ______(7) Used to log leaks. | |
| ______(8) Used on impressed current systems. | |
| ______(9) Includes readings of four check points. | |
| ______(10) Used in performance surveys. | |
| ______(11) 10 percent of the anodes must have test stations. | |
| ______(12) Make entries on the base layout map in conjunction with this form. | |

7. What must be identified before a cathodic protection system can be installed?

8. What does a visual inspection for corrosion of a metal structure reveal?

9. What are potential surveys supplemented with?

**446. State the criteria for effective cathodic protection.**

**Criteria for Effective Protection.** The criteria or standards for cathodic protection, which we are going to cover, are proven to control corrosion. Engineers, in laboratory experiments, have found that a specific metal/alloy, in a specific electrolyte, will corrode at a specific potential (voltage).

When we install a cathodic protection system and measure our various potentials against the engineers' criteria, we can determine if our protection is adequate.

*Structure-to-electrolyte potentials.* The three cathodic protection criteria commonly used for pipelines are all based upon the measurement of structure-to-electrolyte

potentials, with the reference electrode being placed as close to the structure as possible. Each of these protection criteria has certain advantages and limitations. These must be considered before an optimum protection criterion can be selected.

No. 1. A negative (cathodic) voltage of at least −0.85 volt as measured between the structure surface and a saturated copper-copper sulfate half-cell contacting the electrolyte. Determination of this voltage is to be made with the protective current applied.

No. 2. A minimum negative (cathodic) polarization voltage shift of 100 millivolts (mV) measured between the structure surface and a saturated copper-copper sulfate half-cell contacting the electrolyte. This polarization voltage shift is to be determined by interrupting the protective current and measuring the polarization decay. When the current is initially interrupted, an immediate voltage shift will occur. The voltage reading, after the immediate shift, shall be used as the base reading from which to measure polarization decay.

No. 3. A negative (cathodic) voltage shift of at least 300 mV as measured between the structure surface and a saturated copper-copper sulfate half-cell contacting the electrolyte. Determination of this voltage shift is to be made with the protective current applied. This criterion of voltage shift applies to structures not in contact with dissimilar metals.

A structure-to-electrolyte potential of at least −0.85 volt is generally the most practical and economical criterion for well-coated steel pipelines. This is understandable, because the anodic areas on the unprotected structure should not have a potential more negative than about −0.80 volt. Theoretically, corrosion activity should cease when the entire structure is polarized to at least −.0.85 volt. To insure that adequate protection is applied, a potential of −1.0 volt is sometimes used for well-coated, new pipelines. This basic criterion is widely used in areas where fluctuating stray currents exist and drainage bonds are used to reduce the interference. A potential of at least −0.85 volt should also be the criterion in areas where galvanic (dissimilar-metal/alloy) couples exist. The criterion is not extensively used on bare, especially old, steel structures because of the excessive current that could be required to achieve −0.85 volt. For example, polarizing to −0.85 volt would represent a significant waste of energy if all of the unprotected (static) potentials for the structure varied between −0.2 and −0.5 volt. The −0.85 volt criterion is also sometimes difficult to achieve because of depolarization, which can occur in highly aerated soils and waters.

When bare or poorly coated, especially old, steel structures are to be protected, the 300 mV negative potential shift criterion is commonly used. This criterion is also useful in highly aerated soils and waters where significant depolarization can occur. The 300 mV negative potential shift criterion is especially advantageous where the anodic and cathodic areas on the pipeline or structure are not highly localized. It is important to remember that the 300 mV shift criterion can possibly overprotect a new, well-coated pipeline or structure and cause coating damage. The latter is often a problem in low resistivity soils where the overvoltage for hydrogen evolution can be exceeded. Use of the 300 mV shift criterion is particularly hazardous in areas where fluctuating stray currents exist. This criterion must not be used if galvanic couples are involved. For example, a negative potential shift of 300 mV would reduce the galvanic corrosion of steel connected to copper, but it would not necessarily assure complete cathodic protection.

The 100 mV polarization potential shift criterion is also used for uncoated and old pipelines. In general, the limitations of this criterion are similar to those noted for the 300 mV negative potential shift criterion. It is, however, an especially advantageous criterion for conditions where large voltage (IR) drops through the electrolyte are encountered. Therefore, the 100 mV polarization shift criterion is generally not used for structures protected with galvanic anodes, because the current is often difficult to interrupt.

*Maximum pipe-to-soil potentials*. Maximum pipe-to-soil potentials for the materials listed below must be measured directly over the pipe at locations where the piping is nearest the anode groundbed. All piping and underground metallic structures in the vicinity of each groundbed should be checked to determine the potential of each. Maximum allowable pipe-to-soil potentials must not exceed the following values:

| MATERIAL | MAXIMUM POTENTIAL |
|---|---|
| Coated Steel | −2.05 volts |
| Lead | −1.10 volts |
| Aluminum | −1.20 volts |
| Coated Water Tanks | −1.50 volts |

NOTE: The above criteria also apply to POL facilities.

When the maximum pipe-to-soil potentials are reached and all the piping served by the rectifier is *not* protected, additional rectifier groundbeds must be considered. The installed rectifier should be readjusted to produce a maximum permissible design potential when making tests to determine the requirements for the additional rectifier groundbed.

A number of factors and conditions must be considered before a criterion is selected to establish that a pipeline line or structure is adequately protected. Fortunately, however, when the proper criterion is selected and the structure-to-electrolyte potential data are carefully obtained, there is a high degree of assurance that effective control has been achieved.

**Exercises (446):**

1. How can we determine if our protection is adequate?

2. Where must structure-to-electrolyte potentials be read to get an accurate reading?

3. What voltage is measured between the structure surface and a saturated copper-copper half-cell contacting the electrolyte?

4. What position is the protective current in when measuring for a minimum negative voltage criterion of −0.85 volt?

5. What position is the protective current in when measuring the 100 mV or the 300 mV polarized voltage shift criterion?

6. When should corrosion activity cease on well-coated steel pipelines?

7. When is the 300 mV negative potential criterion commonly used?

8. What is the maximum pipe-to-soil potential criteria for coated steel?

**447. Describe the procedures used to take electrical measurements in cathodic protection systems.**

**Field Measurements.** The proper operation and maintenance of any cathodic protection system requires that certain electrical measurements be made in the field. These measure measurements serve two purposes: They tell whether or not the system is functioning as it was designed to function and whether or not it is providing adequate protection; and disclose both sudden and long-term changes in electrical flow through the system in order to furnish clues to the physical state of anodes, operating condition of rectifiers, and changes in the electrical characteristics of the protected and nearby structures.

Field measurements of potential, current, and resistivity provide the information needed to determine the actual operating condition of a cathodic protection system or to determine if cathodic protection is required on an unprotected system. Measurement of the rectifier output (both voltage and current) is a familiar procedure; however, the actual techniques of measuring structure-to-electrolyte and anode-to-electrolyte potentials and anode-to-structure currents, using test stations and soil resistivities, are not so familiar.

*Structure-to-electrolyte measurements.* You must make structure-to-electrolyte potential measurements and keep accurate records of these measurements from the time you first install the cathodic protection system. These records should show the normal structure-to-electrolyte potential value before the cathodic protection was installed. With these records you can determine whether protection is complete, partial, or noneffective. The structure-to-electrolyte potential is one of the most important measurements made in cathodic protection. You make this measurement with a high-resistance voltmeter like the one shown in figure 4-16, and a copper-copper sulfate half-cell like the one shown in figure 4-17.

The negative terminal of the voltmeter is connected to the structure and the positive terminal to the electrode of a copper-copper sulfate half-cell, and the potential is indicated by the voltmeter. The measured potential is said to be "referred to a copper-copper sulfate half-cell." Other types of half-cells are available, however, in actual practice, they are almost never used. This potential value, measured against our standards, will tell the operator whether or not the structure is adequately protected at the point of test. For example, remember that iron and steel structures were adequately protected at a potential of −0.85 volt or more. Any sudden changes in potential indicate either some outside influence (such as stray current) or a change or failure in the cathodic protection system. The basic arrangement of components is shown in figure 4-18.

It is important to insure that good contact is obtained between the components of the circuit. Any high-resistance connection will cause erroneous readings to be taken. The operator must be certain that the porous plug of the reference half-cell is in contact with moist earth (or water in a tank), and that a solid metal-to-metal contact is made between the structure and the test lead to the voltmeter. With soil electrolytes, it may be necessary to scrape down to moist earth or even to dampen the soil with water. Test prods or clips should be wiggled on the metal surface to penetrate any dirt or oxide coatings. In survey work, it is desirable that structure-to-soil readings be taken with the reference half-cell directly over the structure to be tested.

Connection to buried structures being tested is sometimes difficult. The following is a list of possible points of electrical contact: cathodic protection test stations, water or fuel hydrants, exposed service entrances, meter installations, and valve bonnets. It is also important to be sure that the electrical contact is made to the structure proper. Two common causes of trouble here are making contact to the pipeline on the wrong side of an insulating bushing or union and to a valve stem which is insulated from the valve body by packing or seating material.

Sometimes it is necessary to make contact with a buried structure at a point where there is no exposed place of connection. If it can be absolutely determined that the structure is bare, contact may be made by probing down with a steel bar. Under no circumstances should coating be

Figure 4–16. High-resistance voltmeter.

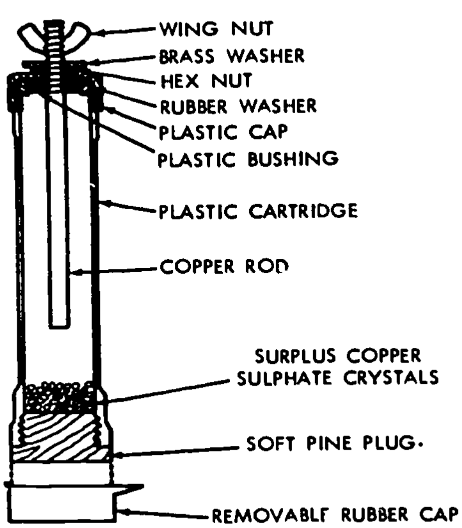



Figure 4–17. Copper-copper sulfate cell.

damaged by steel bar probing. Electrical contact with exposed structures such as tanks, sheet piling, or exposed pipelines pose no difficulty; but good metal-to-metal contact must be assured. Where two structure wires are available, always use the wire that is not carrying current.

*Anode-to-electrolyte potential.* The anode-to-electrolyte potential provides an indication of which lead wire is attached to the anode. Also, by moving the electrode, the location of the buried anode may be pinpointed. An abnormally low potential of anode to electrolyte may indicate a severed lead wire or a dissipated anode.

The measurement of anode-to-electrolyte potential is usually possible only at cathodic protection test stations. This measurement is not necessary where the anode can be physically inspected, as in a water tank or along a wharf. This measurement is made with exactly the same electrical connections as for measuring structure-to-soil electrolyte potential. The positive terminal of the voltmeter is connected to the reference half-cell electrode and the negative terminal to the anode under test. When measuring at a test station, simply connect the negative meter lead to the appropriate terminal to measure either structure or anode potential.

*Anode-to-structure current.* The ability of a cathodic protection system to do its job is directly related to the

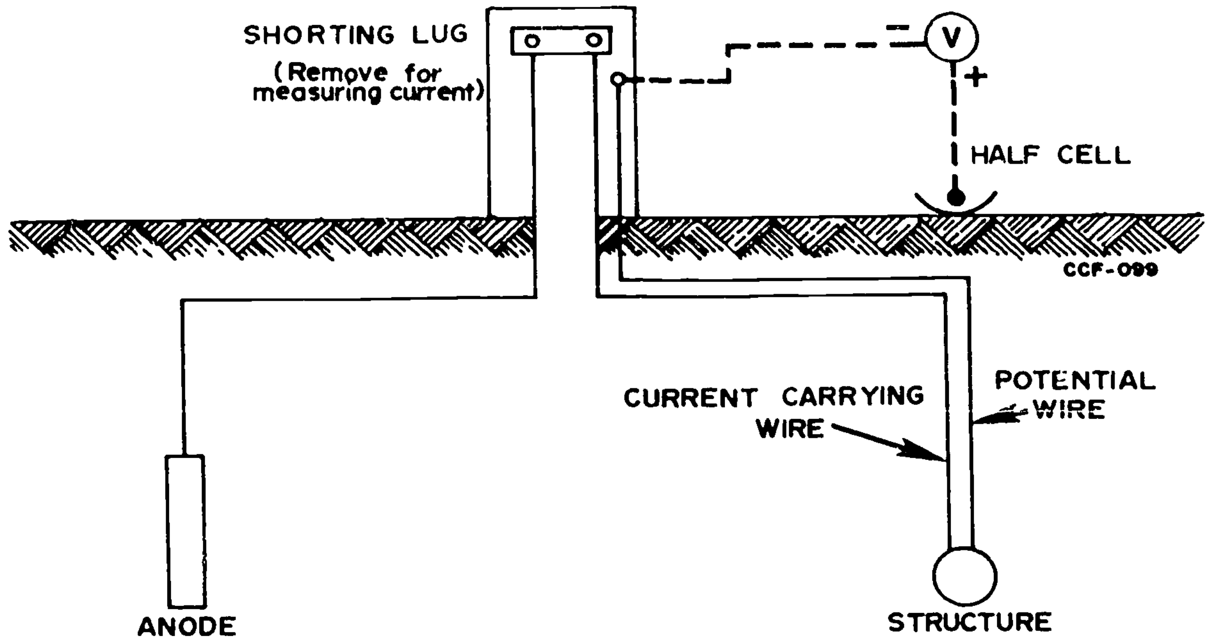



Figure 4-18. Surface type potential-current stations.

amount of current which passes from the anode to the structure. If the current decreases or stops, the amount of protection decreases or stops in direct proportion. A record of anode-to-structure current provides an indication of the level of protection provided to the system by the anodes under test. This measurement is made by inserting an ammeter into the conductor between the anode and the protected structure. In a galvanic anode system, this requires physically breaking into the anode-to-structure connecting lead. In an impressed current system, the electrical connections are similar, except that the meter shunt is usually permanently connected into the circuit and it is only necessary to connect the meter movement across the shunt. As in all DC measurements, it is necessary to observe the correct polarity and start at the highest range of the instrument in order to prevent overloading and damage to the meter.

*Potential measurements of facilities under pavement.* It has been discovered that past methods of measuring structure-to-electrolyte potentials of metallic facilities (pipelines, tanks, metallic sheath cables, etc.) under pavement, using a reference electrode in contact with the pavement, will result in a large error. The most efficient way of obtaining accurate measurements is to install a permanent pavement insert with a removable plug that will allow insertion of a reference electrode. These inserts should be installed in the pavement at points where metallic facilities cross and at least every 100 feet along the route of metallic pipelines or cables. Figure 4-19 shows a typical installation of a 1 5/8-inch plastic insert with a 3/4-inch removable cadmium plated plug. A copper-copper sulfate reference electrode that will easily fit through the hole in the pavement insert is available. The hole beneath the pavement insert should be filled with sand to within 4 inches of the top of the pavement insert to allow the 5¾-inch long and 3/8-inch diameter reference electrode to make contact with the sand. If measurements must be taken immediately after adding sand, a small amount of water should be poured into the hole prior to taking potential measurements with the proper voltmeter. For future measurements, the sand will absorb enough moisture from the surrounding media so that accurate measurements can be made without adding water if a potentiometer-voltmeter circuit or a voltmeter having at least 10-megohm internal impedance is used.

*Potential surveys and leak detection.* One of the many benefits from determining structure potentials is that of pinpointing possible leak locations, much as those on a gas pipeline system. While many leaks are readily found and repaired, there is a significant number of leaks that are not readily located without extensive excavation and pipe damage. Measuring the structure-to-electrolyte (soil) potentials, tests are conducted over the structure at equally spaced intervals such as 25 to 50 feet. This information will indicate, by variation in potential readings, where the structure is most likely to corrode. On an unprotected (no cathodic protection) structure, this would be where the greatest negative values with respect to a copper-copper sulfate half-cell electrode are located. Upon selecting these areas, a resurvey of the structure is made at closer intervals to pinpoint the most corrosive area. While this method is not always 100 percent successful, it is a valuable tool under most circumstances.

*Test stations.* Cathodic protection test stations are simply leads which are brought to the surface of the ground or to some other easily accessible place so that electrical measurements may be made conveniently. There are two basic types of stations, subsurface type and surface. These

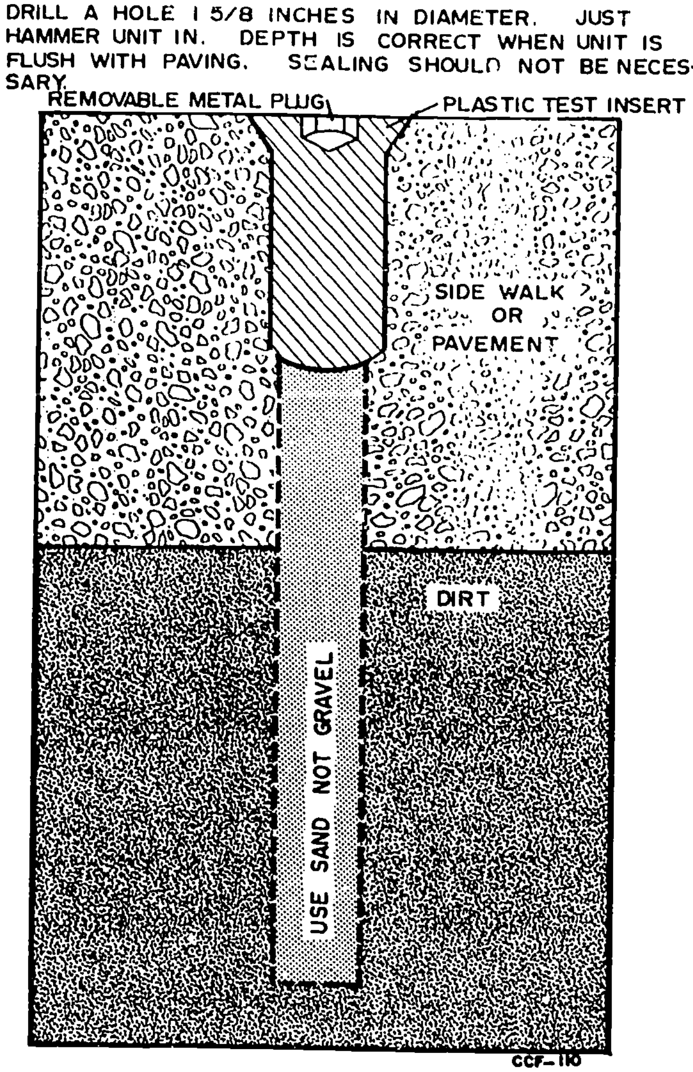



Figure 4–19. Plastic test insert.

two types of stations may be installed for potential only or potential-current measurements. Since the use of the test stations usually requires making a physical disconnection between the anode and the structure, it is extremely important to insure that the connection is properly restored at the completion of the testing. Where shorting lugs are used, be sure that the nuts or screws holding the lugs in place are firmly snugged down and that a good metal-to-metal contact is made. Where galvanic anodes are involved, test leads should be terminated on terminals.

Since cathodic protection systems are electrical in nature, it is important that the current be allowed to flow where it is needed without unnecessary loss or restriction. The two usual causes of loss and restriction are high-resistance connections and poorly insulated connections. Connections to the structure will be thermite welded or brazed and then insulated from the electrolyte. Conductor splicing should be avoided where possible. Permanent conductor splices will be done by thermite welding or crimped pressure connection with proper ratchet tools.

The simplest and best method of attaching leads to structures and obtaining a good electrical connection is the thermite welding process. Thermite welding is a means of permanently fastening copper conductors to steel or iron structures or to another copper conductor. Powdered copper oxide and aluminum are burned to provide heat and molten copper. The molten copper flows over the conductor and the structure, permanently welding them together. The equipment is light and portable, and no outside source of heat or power is required. The thermite weld furnace must be of the proper size for the pipe and wire size encountered. Underground splices are adequately insulated by three wraps of insulating electrical tape.

The completed thermite weld and exposed copper wire must be coated with a thermite weld cap filled with mastic. The cap must not be installed until after the weld has cooled sufficiently to prevent mastic from melting or burning.

**Exercises (447):**

1. What two purposes do electrical measurements serve in a cathodic protection system?

2. When should a record of structure-to-soil measurements be initiated?

3. Which is the most important measurement made in cathodic protection?

4. What two test instruments are used to measure cathodic protection?

5. How are the meters listed in the preceding question connected?

6. What indicates whether or not the structure is adequately protected?

7. What do sudden changes in potential indicate?

8. What could give you an erroneous reading when taking structure-to-electrolyte potential readings?

9. What will an anode-to-electrolyte potential indicate?

10. How is an anode-to-structure current measurement made?

11. What is the most efficient method of measuring structure-to-electrolyte potentials under pavement?

12. How can a leak in a pipeline system be detected without excavating the pipe?

13. What is provided in the cathodic protection system to make the electrical measurements more convenient?

14. What are the two methods of attaching conductors to the structure?

15. How are underground thermite welds insulated from the electrolyte?

**448. Describe the procedures used to perform resistivity tests.**

**Resistivity.** The ability of soil or water to conduct electricity is closely related to the rate at which buried or immersed structures will corrode. The lower the resistance to current flow, the higher the rate of corrosion. The practical measure of the ability of a material to resist the flow of electricity is known as resistivity. Resistivity is defined as the resistance in ohms between opposite faces of a 1-centimeter cube of material. The basic circuit for the measurement of soil resistivity is shown in figure 4-20. While resistivity measurements can be made using a voltmeter and ammeter as shown, most resistivity measurements are made using the Vibroground instrument.

*Soil resistivity.* Soil resistivity is found by measuring the current flow through a specified section of earth, give the average soil resistivity down to a depth about equal to the pin spacing. By changing the pin spacing, the resistivity to other depths can be determined.

Polarization and galvanic effects between the electrodes may cause errors in the calculated resistivity when only one DC measurement is made. These effects may be eliminated by reversing the DC current and averaging the results, or by using an AC current and AC measuring equipment. Earth resistivity meters use alternating current for this reason. Figure 4-21 shows how the instrument is connected to the field soil probes or pins. The Vibroground instrument reads directly in ohms.

*Water resistivity.* Water resistivity is usually determined by calculation from its inverse characteristic, conductivity. Conductivity is the ability of a material to conduct electricity and is numerically equal to the reciprocal of the resistivity. The basic unit of conductivity is ohms per determining the voltage drop across all or part of the earth under test and using these measured values to calculate the resistivity by formula. Figure 4-20 shows the basic circuit used for this determination. The resistivity (P) is calculated from the formula:

$$(RHO)\ P = \frac{191\ AP}{1}$$

Or

$P = 191\ AR$

Where

$A$ = pin spacing in feet

$R$ = instrument reading in ohms

The formula may be further simplified to:

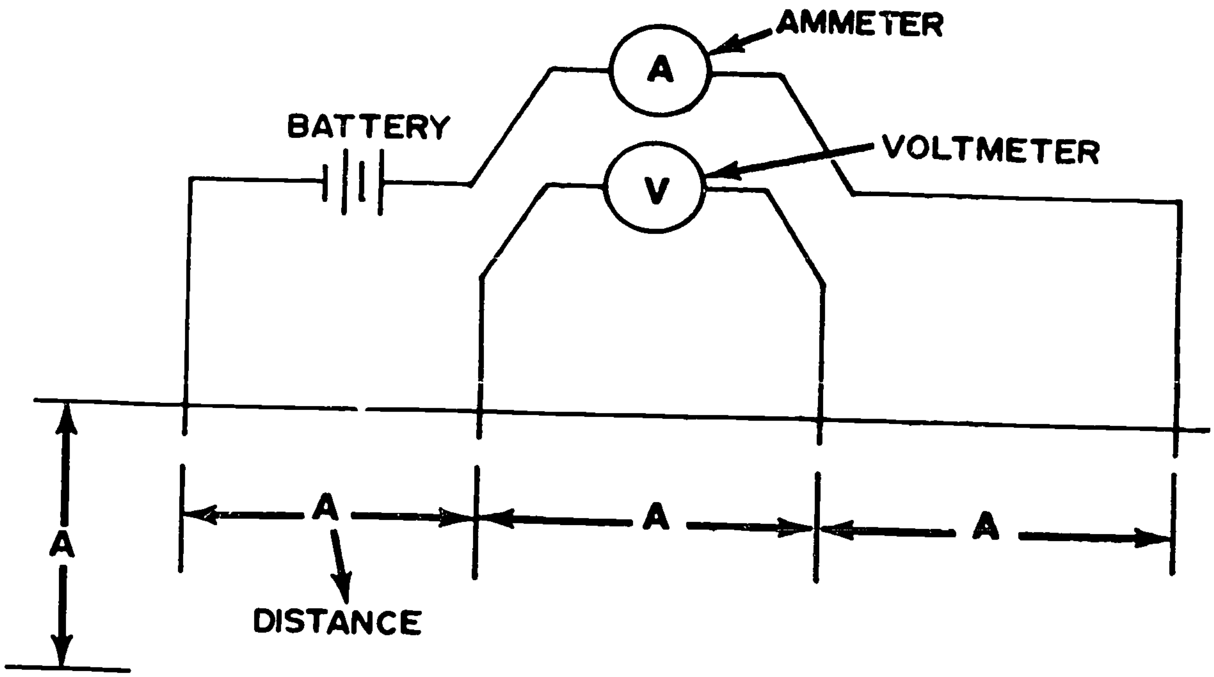
$P = KR$

Where

$K = 191A$

If the soil pins are spaced as shown in table 4-5, the soil resistivity is simply calculated by multiplying the instrument reading by K from the table. A commonly used pin spacing is 5 feet so that K = 1000. This calculation will centimeter, but most water analyses report conductivity in millionths of ohms (or micro ohms) per centimeter. The conductivity of every domestic water supply used by the Air Force is reported as a part of the annual water analysis by the U.S. Geological Survey for CONUS installations and some overseas installations.

Limitations of the 4-pin method can be overcome by using the single rod probe method or by measuring the resistivity in the soil box. The single rod probe measures the soil resistance between two electrodes on a single probe. It will measure the local soil resistivity in the immediate vicinity of the tip of the probe placed into the soil or liquid. It is useful for obtaining resistivities of liquids or soil resistivities in excavations and trenches. Similarly, the soil box method measures the resistivity of a small sample of electrolyte. This method of obtaining soil resistivity is a modification of the 4-pin method applied to small samples

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A SPACING IN FEET

(RHO) AVERAGE RESISTIVITY TO A DEPTH OF 'A' FEET IN OHM CENTIMETERS

Figure 4–20. Basic soil resistivity circuit (4-pin method).

TABLE 4–5
RESISTIVITY

P = KR

| Normal Pin Spacing | Actual Pin Spacing | K |
|---|---|---|
| 2'6" | 2'7" | 500 |
| 5'0" | 5'3" | 1000 |
| 7'6" | 7'10" | 1500 |
| 10'0" | 10'6" | 2000 |
| 15'0" | 15'9" | 3000 |

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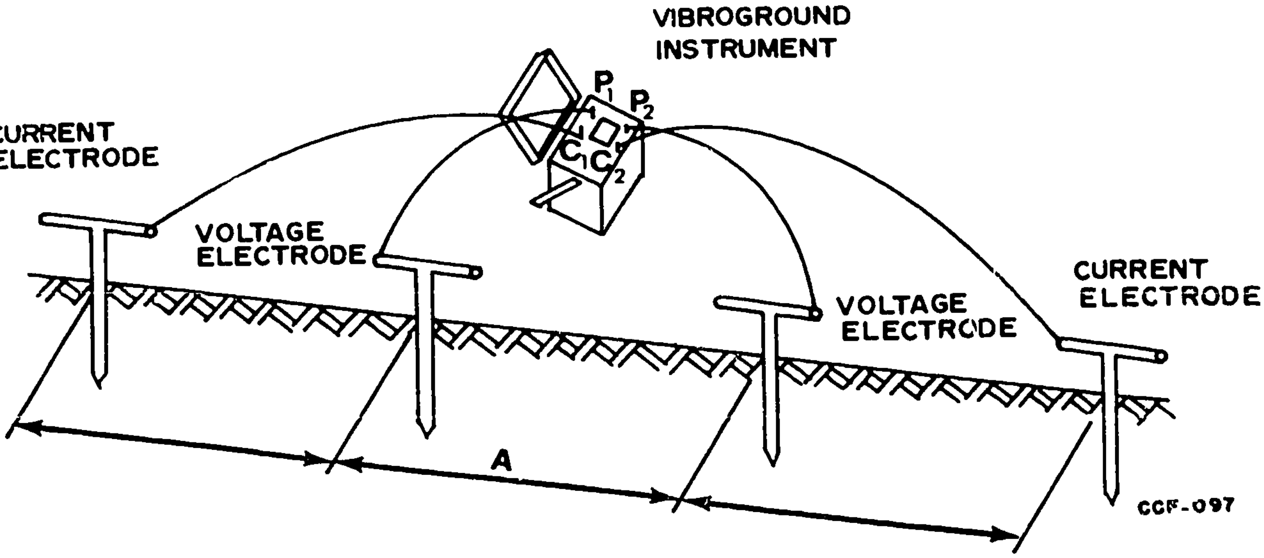


Figure 4–21. Field measurement of soil resistivity (4-pin method).

of soil or water. It is useful in showing the variation of soil resistivities between specific samples at a location. Soil boxes are made of a nonconducting material and are so proportioned that when the box is filled level, the resistivity in ohm-cm is equal to the change in potential between the potential pins, divided by the change in current applied at the current electrodes. The soil boxes are usually made of plastic, with the current electrodes at the ends made of zinc, and the potential electrodes are made of brass or copper. When an electrolyte is placed in the soil box, a galvanic current and potential may be set between the current electrodes and the potential electrodes. The potential and current flow caused by the galvanic action would be the first reading taken. The second reading would be taken after an external potential was applied to the current electrodes.

It is important that tests using small soil samples be properly conducted. Generally, a large number of tests are required in order to establish average conditions along a pipeline. A major limitation of these small-sample techniques is the need to auger/excavate to the pipeline depth.

In addition to predicting corrosion activity, soil resistivity data is required for designing cathodic protection systems. Soil resistivity must be known in order to calculate the current output of a galvanic anode. This determines the number of anodes required for protection and where the anodes should be located along the pipeline. For an impressed current system, soil resistivity is used to calculate the theoretical resistance of the groundbed. This is an important part of the total circuit resistance. Since it is desirable to minimize the total circuit resistance, the groundbed should be located in a region of low resistivity.

**Exercises (448):**

1. What does soil resistivity have to do with corrosion?

2. How are most soil resistivity measurements taken?

3. What is the most commonly pin spacing used when taking soil resistivity tests?

4. To what depth will the soil resistivity formula calculate?

5. How can polarization and galvanic effects be overcome?

6. How is water resistivity determined?

7. How is the soil box method used to measure soil resistivity?

8. How are soil resistivity measurements used for new systems?

**449. Specify the frequency of measurements for cathodic protection systems.**

**Frequency of Measurements.** It is desirable to make a series of electrical measurements on a newly installed system to determine the initial level of cathodic protection.

*Galvanic anode system.* After the initial series, measurements should be made quarterly for the first year. This will enable the corrosion engineer to identify deficiencies (from settlement) and program corrective action. After the first year of operation, measurement will be made annually unless the major command requires more frequent testing. Data must be recorded on AF Forms as outlined in AFM 85–5.

*a.* Structure-to-electrolyte potential. The primary measurement to be made is that of structure-to-electrolyte potential, since this determines the adequacy of protection. Figure 4-18 shows the basic arrangement for making this measurement. The following spacing of potential measurements shall be made initially and annually. In congested areas, structure-to-electrolyte (soil) potentials shall be measured at service risers and at points over the main farthest from the anodes. Potential measurements over long pipelines shall be made at points farthest from the anodes, but in no case farther than 1000 feet. The measuring and recording of structure-to-electrolyte potential can be used to determine the level of protection and the trend of changes in protection. Gradual changes in potential are indicative of anode corrosion, changes in soil resistivity, or distant interference, shorted insulation, or changes in piping.

*b.* Anode-to-electrolyte potential. The measurement of anode-to-electrolyte potential serves as a check of lead continuity, anode condition, and location (peak potential occurs directly over anode). Where test stations are provided, this measurement should be made at the same time as that of structure-to-electrolyte potential.

*c.* Structure-to-anode current. The rate of anode metal loss is directly dependent on the rate of current flow between the structure and the anode. This current flow is measured to give an indication of proper anode operation and to allow calculation of anode life. Where test stations are provided, this measurement should be made at the same time as that of structure-to-electrolyte potential.

*Impressed current systems.* Monthly inspection of cathodic protection rectifiers must be made by the cathodic protection technician to insure that all components are in proper operating condition and that the unit is producing adequate DC current to provide complete protection. The inspection includes measurements of current and voltage output, maximum and minimum potentials and a check of components for deficiencies. Oil immersed rectifiers require additional inspection as listed in AFM 85–5.

The first step in conducting a rectifier inspection is to measure both current and voltage output and record the readings in the "as found" columns, AF Form 491. Most rectifier assemblies include both a voltmeter and an ammeter for measuring applied potential and impressed current. Some meters are permanently connected into the circuit and continuously read the voltage and current. Other meters are normally disconnected from the circuit and are energized by pressing a switch or button, as shown in figure 4-22. Use table 4-6 for the rectifier voltage sequence. When using a "press to read" switch, press and release the switch slowly three or four times before recording the readings. Because these switches are idle for long periods between uses, the contacts sometimes do not seat properly and may make a high-resistance connection. Actuating the mechanism carefully for several times allows the movement to "free up" and the contacts to meet properly. Compare the rectifier output readings with those of the previous inspection. Adjust the voltage, if necessary, to maintain the required current output. Any significant change indicates a component failure in the rectifier or a change in the system or system environment.

Inspection of the individual rectifier components is made to insure that all parts are operating properly to maintain protection of the structure. The point of maximum potential and three points of minimum potential for each rectifier system must be selected each year from the annual performance survey. The location of these points must be recorded in Section 9 of AF Form 491. Also, the current required to provide complete protection, as determined during the initial start up or the annual performance survey described in AFM 85–5, must be recorded in Section 8 of AF Form 491. The four potential measurements must be made after assuring that the required current output is provided. The data obtained must be reviewed by the corrosion engineer, who will provide guidance if any changes in current output are required.

Meters in each rectifier unit must be checked for accuracy each year. A portable instrument of known accuracy is used to check the unit meters by measuring the voltage across the output terminals and comparing this reading with that of the unit meter, and by inserting the test ammeter in the output circuit and comparing its reading to that of the unit ammeter. The test voltmeter should be at least as sensitive (in ohms per volt) as the unit voltmeter being checked. The test ammeter should offer less resistance to the circuit than does the unit ammeter. All rectifiers should have a shunt mounted on the front panel to check the accuracy of the current output. The shunt will be marked as to the amps/millivolt rating which should be used in calculating the current.

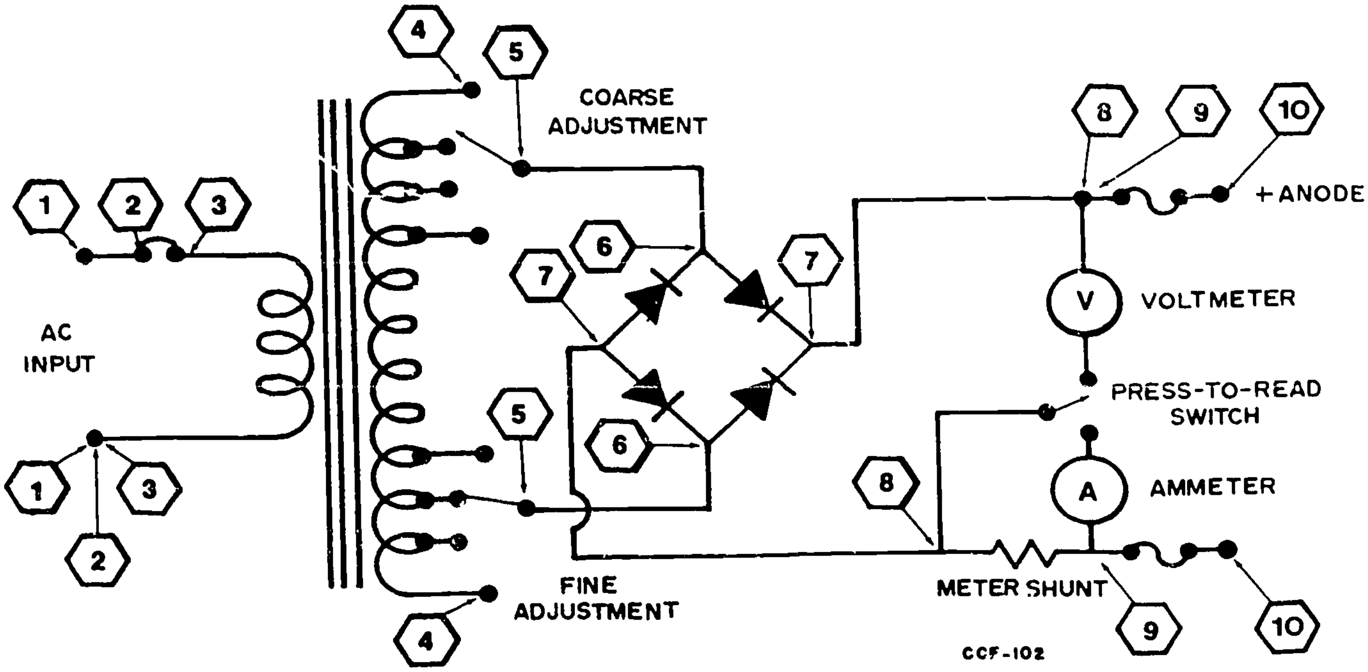


Figure 4–22. Voltage test sequence for rectifiers.

TABLE 4–6
VOLTAGE SEQUENCE FOR RECTIFIER TROUBLESHOOTING

| Probe Points | Measurement Indicates |
|---|---|
| 1-1. | A.C. voltage from the disconnect switch. |
| *2-2. | A.C. voltage to the curcuit breaker and/or fuse. |
| *3-3. | A.C. voltage to the transformer primary winding |
| 4-4. | A.C. voltage through the transformer. |
| 5-5. | A.C. voltage through top adjustment connections. |
| *6-6. | A.C. voltage to the rectifier. |
| *7-7. | D.C. voltage from the rectifier. |
| *8-8. | D.C. voltage to the metering terminals. |
| 9-9. | D.C. voltage to the protective fuse terminals. |
| 10-10. | D.C. rectifier voltage output. |

*Usually these readings cannot be made without removin panel from the rectifier.

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**Exercises (449):**

1. How often are electrical measurements made on galvanic anode systems the first year of use? After the first year?

2. What is the primary measurement to be made on galvanic anode systems?

3. What can the records from structure-to-electrolyte measurements be used for?

4. What is the purpose of anode-to-electrolyte measurements?

5. In anode-to-electrolyte potential measurements, where is the peak potential measured?

6. When are structure-to-anode measurements taken?

7. How often are the rectifiers in impressed current systems inspected?

8. What potentials must be selected each year in the rectifier system?

9. Where are the locations of these points recorded?

10. How often are the meters in the rectifier units calibrated?

## 4-4. Troubleshooting

Because cathodic protection systems are located outdoors, they are subject to the elements. These effects can play a major role in your ability to control corrosion. In this section you will learn troubleshooting procedures and how to remedy problems that may arise.

**450. Specify troubleshooting procedures for cathodic protection systems.**

**Galvanic Anode Systems.** If protection is good, the potential value will read approximately −0.85 volt. A value nearer zero than −0.85 volt indicates partial protection and may indicate that the leads to one or more of the anodes are broken, or that the anodes are "used up."

If you check the anodes and their leads and find them satisfactory but the potential is still low, then search for an electrical leak or "holiday" in the protective coating on the structure. If you have a leak on the structure, you will have a sharp drop in potential at that point. To restore the efficiency of the protection system, the leak must be repaired.

You can check the anodes' physical condition in the same way that you check the structure. Using the same instruments, connect the positive terminal of the voltmeter to the half-cell electrode and the negative terminal to the anode under test. A lower-than-normal potential means gas blockage (the formation of a film of gas on the anode surface). An above-normal potential shows that the anode is corroded away. Both of these situations are accompanied by severe drops in the structure-to-anode current. The anode-to-electrolyte measurement is not necessary where the anode can be physically inspected. Table 4-7 describes troubleshooting procedures.

**Impressed Current Systems.** If inspection reveals that a unit has failed (or is near failure), follow basic troubleshooting procedures to locate faulty components and restore the rectifier unit to operation. The simplest means of troubleshooting is to follow the flow of electricity through the rectifier unit, component by component. Figure 4-22 shows the sequence of checking through a rectifier with a voltmeter using nine tests. This same procedure can be used on any rectifier circuit from a single-phase half-wave unit to a three-phase bridge. Be sure to use AC meters on the AC side of the stacks and DC meters on the DC side of the stacks. Table 4-6 shows the voltage test sequence for troubleshooting a rectifier.

Before troubleshooting a unit, study the circuit diagram furnished with the manufacturer's instructions that are mounted in the rectifier cabinet. If no circuit diagram is available it is usually worthwhile to trace out the circuit and develop a diagram. A copy of this circuit diagram should be filed with other recording drawings. Voltage test points are not limited to those shown in figure 4-22. Intermediate points can and should be checked in a search for loose connections and broken conductors.

Turn off the rectifier by throwing the AC circuit breaker and the outside disconnect switch before touching parts to check for heat buildup on loose connections. Be sure test meters are properly connected and range selected is high enough to prevent meter damage. Observe the same safety practices as when inspecting other electrical equipment. The cause of rectifier failure may have left hazardous conditions not usually encountered in electrical equipment.

TABLE 4-7
ANODE TROUBLESHOOTING

| CONDITION | CAUSES | METHOD TROUBLESHOOTING | REMEDY |
|---|---|---|---|
| 1. Structure-to-electrolyte potential is -0.85 or slightly higher (complete protection). | System O.K. | None Needed | None Needed |
| 2. Structure-to-electrolyte potential is lower than -0.85 and higher than original or unprotected structure-to-electrolyte condition. | a. Lead wire between anode and structure broken. | a. Check potential between anode and copper sulfate electrode. Potential should be -1.50 volts or higher. Also, make continuity tests on structure leads and measure anode current output. | 2. Replace the broken lead wire. |
| | b. Coating damaged or deteriorated. | b. Conduct coating conductance tests and/or Pearson type over-the-ground holiday detector tests. | b. Excavate lime and patch coating or install additional anodes. |
| | c. New section of structure added without added cathodic protection. | c. Check as-built or construction records. | c. Install additional cathodic protection. |
| | d. Insulators shorted - bare structure shorted to protected structure. | d. Test all insulated fittings. | d. Replace shorted insulated fittings. |
| | e. Improper design - not enough anodes installed. | e. Measure current output of anodes and conduct current requirement tests. | e. Install additional cathodic protection. |



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**Rectifier Troubleshooting Procedures.** The following are the troubleshooting procedures to be used for locating the cause of reduced or interrupted rectifier output:

*a*. If no output voltage is indicated on the rectifier meter, make the following checks and repair as necessary:

(1) Check AC circuit breaker, DC fuses and AC disconnect switch and fuses. If circuit breaker or fuses are blown, check the reason for the interruption and make necessary repairs.

(2) Visually check for evidence of lightning damage or excessive heating in the rectifier cabinet. Also, strange odors indicate heat damage.

(3) Check the DC output voltage with the multimeter connected across the rectifier output terminals. If no voltage is indicated, repair the meter or wiring.

(4) Check the DC fuses, fuse holders, and con[illegible]

(5) [illegible]sing an AC meter, check the disconnect switch for supply voltage, blown fuses or loose connections. If no disconnect switch has been installed, install one.

(6) If AC voltage is not available to the disconnect switch, repair the power source trouble.

(7) If voltage is available from the disconnect switch but not to the rectifier stacks, open the disconnect switch and check for continuity through the AC circuit breaker. Trouble may be in the switch, or wiring, or terminal connection.

(8) Check the AC power supply through the transformer to the rectifier stacks by testing AC voltage across the fixed center terminals of the coarse and fine adjustments. (CAUTION: Do not make this check in an oil-cooled rectifier when terminals are submerged.)

(9) Check the rectifier stack for DC output voltage. If there is input voltage but no output voltage and all terminal connections are tight, the stacks may be defective and should be checked for opens or shorts.

*b*. If the DC voltage is normal at the rectifier output terminals, but no current flow is indicated on the ammeter, make the following checks:

(1) Check for current output with the multimeter. The ammeter may be defective, the current may be too small to register on the meter, or connections and wiring may be defective.

(2) If no current is flowing, there is an opening in one of the external DC leads. Visually check for recent excavations between the rectifier, and both the anode bed and the structure.

(3) If the open circuit is in the buried cable to the anode bed, it may be found by using a pipeline locator or by making an over-the-cable potential survey with the rectifier set for minimum potential. The negative terminal of the high-resistance voltmeter must be connected to the negative (to structure) DC output of the rectifier while the copper-copper sulfate electrode is moved over the route of the buried cable.

(4) In water storage tanks, the open circuit may be at the negative lead connect to the tank (bolted instead of thermite welded) or in the conductor to the anodes. Also, the anodes may be consumed, the conductor may be broken with the anodes lying at the bottom of the tank, or the anodes may be above the low water level. Generally, a visual check will reveal these conditions.

*c*. If the output voltage is normal and the amperage is noticeably lower, check to determine if some of the anode bed has been lost through excavation or deteriorated connections. Check as in paragraph b(3) above.

*d*. If the output voltage is normal and the amperage decreases slowly over a long period of time, the anode bed resistance has increased due to gas blockage or dry soil; or the anodes may be approaching exhaustion, requiring replacement. Dry soil may be suspected during the dry season if the anode installation is relatively new. Soak the anodes by flooding the area to restore the electrolyte. If the low amperage persists, carefully uncover the tops of the anodes (do not damage anode leads or header cable) and backfill with pea gravel from the top of the coke breeze to within 6 inches [illegible] level to allow gas dissipation. If the anodes a[illegible]ng their design life, the first in the string may be ex[illegible]ated for inspection to determine if the anodes require replacement.

*e*. If the output voltage is very low and the amperage is very high, the DC circuit is shorted and the structure is not protected. Check the circuit in the rectifier and at the output terminals.

*f*. Some rectifier circuits include capacitors, fusing, lightning arresters, current control rheostats, and noise interference filters. If this equipment fails, it may be necessary to remove it from the circuit until replacement can be obtained. Capacity of the component must be considered in replacement, particularly where evidence of heating is found.

*g*. The most frequent impressed current system troubles are blown fuses, loose terminals, lightning damage, faulty meters, and open circuit breakers.

*h*. Table 4-8 contains additional troubleshooting information.

**Exercises (450):**

1. What will the potentia[illegible]alue read if the protection is good in a galvanic ano[illegible]ystem?

2. What does a low potential value indicate in a galvanic anode system?

3. What does a sharp drop in potential at a particular point on the structure indicate in galvanic anode systems?

TABLE 4-8
IMPRESSED CURRENT TROUBLESHOOTING

| CONDITION | CAUSES | METHOD OF TROUBLESHOOTING | REMEDY |
|---|---|---|---|
| 1. Rectifier output same as previous test. Potential reading -0.85 minimum for steel. | System O.K. | None Needed | None Needed |
| 2. Rectifier output changed slightly from previous test. Potential readings slightly lower or higher than design limits. | Polarization. Electrolyte resistance change. Extension or retirement of small percentage of structure under protection. | Potential survey to determine extent of over or under protection. | Adjust rectifier taps to obtain desired protection. |
| 3. Zero D.C. Voltage Output | a. Faulty rectifier voltmeter or wiring. | a. Check output with multimeter. Check for loose connections or broken wiring. | a. Replace meter and repair wiring. |
| | b. Circuit breaker off (A.C.) | b. Check for shorts or overload caused breaker to open. | b. Repair damage and close breakers |
| | c. Disconnect switch off or fuses blown (A.C.) | c. Same as above. | c. Repair damage, replace fuses and close connect. |
| | d. A.C. supply interrupted (A.C.) | d. Notify responsible electric shop of the interruption. | d. Shop will repair. |
| | e. Transformer circuit trouble (A.C.) | e. Check output at fixed center terminals of course and fine tap adjustments. | e. Replace damaged transformer or tighten tap connections. |
| | f. Rectifier stack damage | f. Check rectifier input voltage (A.C.) rectifier output voltage (D.C.). Visual check for dirt, heat indications, and loose connections. | f. Tighten loose connections and clean/replace damaged stacks. |

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4. If the structure-to-electrolyte potential is nearer zero than −0.85 and the cause is that the coating is damaged, how would you troubleshoot for this fault and how would you remedy the problem?

5. What is the simplest way to troubleshoot the rectifier unit in the impressed current system?

6. What should be done to the rectifier unit before checking internal components for heat and loose connections?

7. If no output voltage is shown on the rectifier meter and there is input voltage but no output voltage and all terminal connections are tight, what is the problem?

8. What would cause the anode bed resistance to increase slowly over a long period of time?

9. List the most frequent impressed current system troubles.

10. What should you do if the DC voltmeter shows zero output on a rectifier and the AC circuit breaker is off?

CHAPTER 5

# Fire Alarm and Intrusion Alarm Systems

FIRE AND THEFT takes a terrible toll in both property and lives, and any loss in this area is too much. The Air Force protects its property and personnel with fire alarm and intrusion alarm systems. The effectiveness of these systems depends on the installation, inspection, and maintenance that they receive. The primary method of operation is electrical and, as an electrician, you may be directly involved in the operation of these systems.

## 5-1. Fire Alarms

PP Fire, for millions of years, has been man's most versatile and powerful servant. The progress of the human race's technology has paralleled its ability to harness the effects of heat energy in its many forms. Without the advent of this energy, it is quite doubtful that man could have survived through the ages. However, this docile servant can, in an instant, become a raging tyrant, destroying that which it has created and those which it has served. It is this fact that has occupied man in his endeavors to control his servant. This control may take the form of a warning system, a method of extinguishing, or a method of isolating the fire condition. The purpose of this unit of instruction is to explore these systems.

### 451. Identify statements pertaining to the purpose and types of fire alarm systems.

**Purpose of Fire Alarm Systems.** Fire alarm systems provide a direct, intelligible, and reliable means of summoning the fire department to a fire, thus reducing the time between when a fire is detected and the time proper firefighting equipment arrives on the scene. It also warns the occupants of the structure that a fire condition exists so that they may take action to remove themselves from danger. S[illegible]es of fire alarms automatically detect fires and trans[illegible] alarm signals. Other systems such as sprinkler or delug[illegible]ms not only detect and transmit an alarm signal but also begin to extinguish the fire automatically before firefighters arrive.

**Types of Fire Alarm Systems.** Fire alarm systems are either coded or uncoded according to the type of signal transmitted. The type of system is further broken down into manual or automatic, depending on the method of actuation.

*Coded system.* The coded systems transmit, record, and sound a signal identifying the position of the transmitter or actuating device from which the signal originates.

*Uncoded system.* The uncoded alarm system provides an audible, visual, or combination of signals but does not make a permanent record.

*Manual system.* The manual system, as its name implies, requires manual operation for actuating the system and operating the transmitter. In a manual system, other than fire-reporting telephones, signals originating from fire alarm boxes may produce either coded or noncoded signals.

*Automatic system.* In the automatic fire alarm system, a unit called a detector is used. Detectors operate automatically in response to flame or abnormally high temperatures. The systems may also have manual stations (pull stations) to permit manual transmission of fire alarms. Automatic systems may produce either coded or uncoded signals.

*Classifications.* The two general system classifications recognized are local and central station systems. Local alarm systems are systems in which the alarm or supervisory signal sounds in the protected area. They are primarily for notification of occupants. The central station systems are systems in which the alarm circuit sounds a warning device in the area protected but also transmits a signal to a central location, usually the base fire department alarm center.

*Electrical circuits.* The electrical circuit may be one of two different types, nonsupervised or supervised. The nonsupervised circuit is the most simple, being made up of a source of power, the manual activation station, and the alarm buzzer. In this circuit, a possible fault or malfunction, such as loss of power or a broken wire, could occur without any notice being given, thus, the fault might go undetected for a considerable period of time.

In the supervised circuit, provisions are made to signal an alarm or malfunction that may occur. By doing so, any [illegible]ormal [illegible]ence will be signaled and dealt with [illegible]tly.

**Exercises (451):**

Indicate whether each of the following statements is true or false by placing a T or F in the blank. Correct any false statements.

_____ 1. The purpose of a fire alarm is to warn building occupants of danger and summon help.

_____2. A coded alarm system designates the location of the signal.

_____3. An uncoded alarm system provides an audible signal only.

_____4. M[illegible]ms are not coded.

_____5. Automatic systems will always use some form of detector.

_____6. Local alarms are normally transmitted to the base fire department.

_____7. A supervised circuit will signal a power failure in the alarm system.

**452. Give specific details about the application and theory of operation of fire alarm systems.**

**Application and Theory of Operation.** We have already covered transformers, rectifiers, batteries, magnetism, and basic circuits. We will now tie this information together while discussing manual and automatic fire alarm systems and their components.

**Manual Systems.** The manual alarm system is basically composed of a power source, pull station (switch) circuit conductors, and bells. A basic manual system is shown in figure 5-1. When the pull station is activated, a set of contacts is closed and completes [illegible] current path through the bell. The bells will ring until the pull station is restored to normal condition.

NONSUPERVISED CIRCUIT

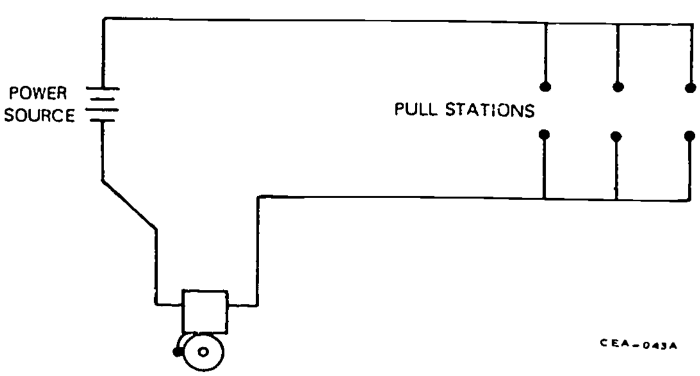



Figure 5–1. Manual alarm system.

*Supervision.* Supervision of fire alarms is common. This additional circuit warns when operating capability is lost through a broken or shorted wire or loss of alarm circuit voltage. Refer to figure 5-2.

The supervision is provided in t[illegible]owing way. The source of power in the circuit passes along the line to the manual station and an inline resistor, the power stops at the manual station because the contacts remain open until it is activated while the same power goes to the inline resistor and 10 milliamps are allowed to pass through to hold open the circuit to the trouble buzzer by means of an electromagnetic switch. As long as power is on, the circuit buzzer will not sound. When power is interrupted because of a broken or shorted wire in the circuit, or for any reason, the electromagnetic switch is released. It closes on the trouble buzzer circuit, which has its own source of power (batteries); therefore, the trouble buzzer sounds until the trouble is corrected or the batteries wear out.

The current flow in the supervised circuit is small, usually 10 milliamps or less. The relays used in these circuits have small contacts and coils with small wire and lots of turns. Because of the large number of turns on these coils, it is possible to receive a severe physical shock from the coil when the circuit is broken.

*Testing.* The system must be arranged so that it can be tested periodically. Such tests are best conducted in connection with evacuation drills, and the alarms sounded in the tests should be the same as those produced under anticipated emergency conditions.

The basic test circuit is shown in figure 5-3. The 10-milliamp current flows through the trouble buzzer as before, but also flows through an additional alarm electromagnetic switch and a manual by operated set of contacts. The manual contacts are wired the same as a pull station. The 10-milliamp circuit is not strong enough to energize the alarm electromagnet. But what happens if the pull station is activated? The [illegible] is shunted or bypassed, and the full voltage [illegible] current from the power supply pass through the alarm electromagnet switch. This will energize the bell. With the additional manual contacts on the alarm electromagnet we can test the alarm bell by pushing the contacts closed and simulate activating a pull station.

**Automatic System.** Most automatic fire alarm systems operate by varying the current flow through a network of circuits. Current flow is changed by increasing the voltage applied to the circuit or the resistance in the circuit. The amount of resistance in the circuit can be increased or decreased by relays, which would change the characteristic of the circuit.

Automatic detectors can be considered as switches in the system. There are many, many types of detectors; but all detectors are either open or closed. Detectors may operate on fixed temperature, rate of rise, [illegible] sampling, smoke or combustion-particles, flame flicker or photo conductive principles.

The automatic alarm using open type detectors works on the same principle as the pull station. The detector contacts

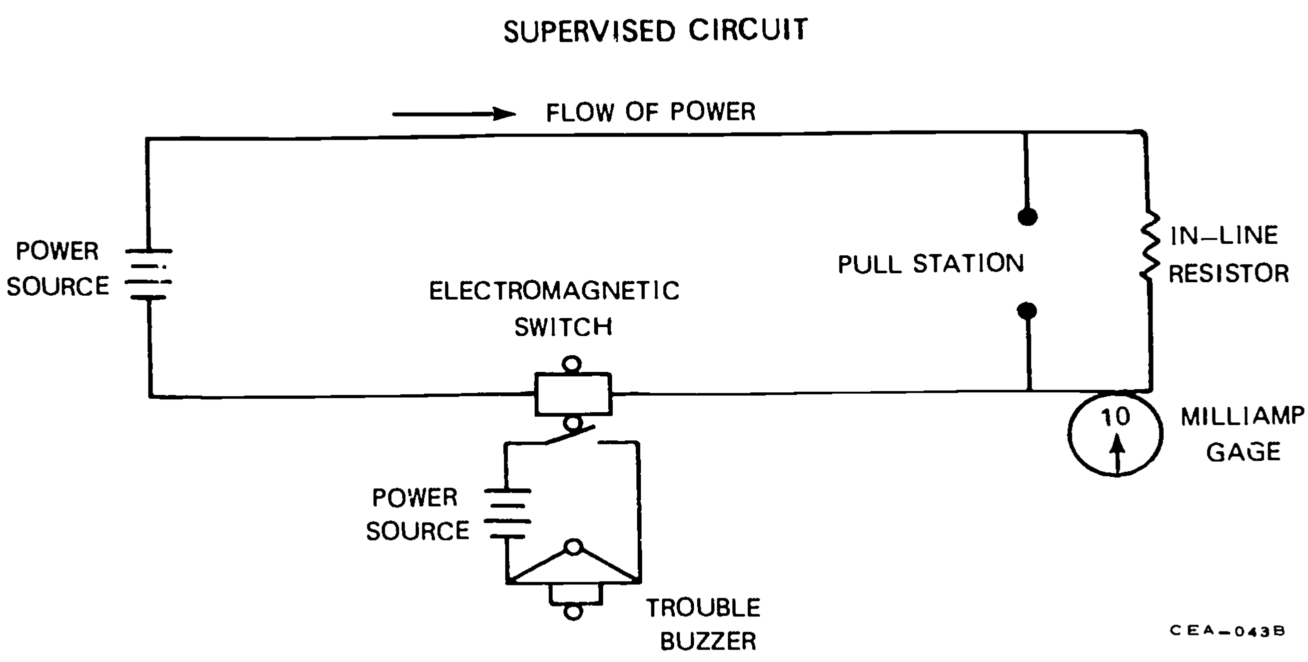



Figure 5–2. Supervised alarm system.

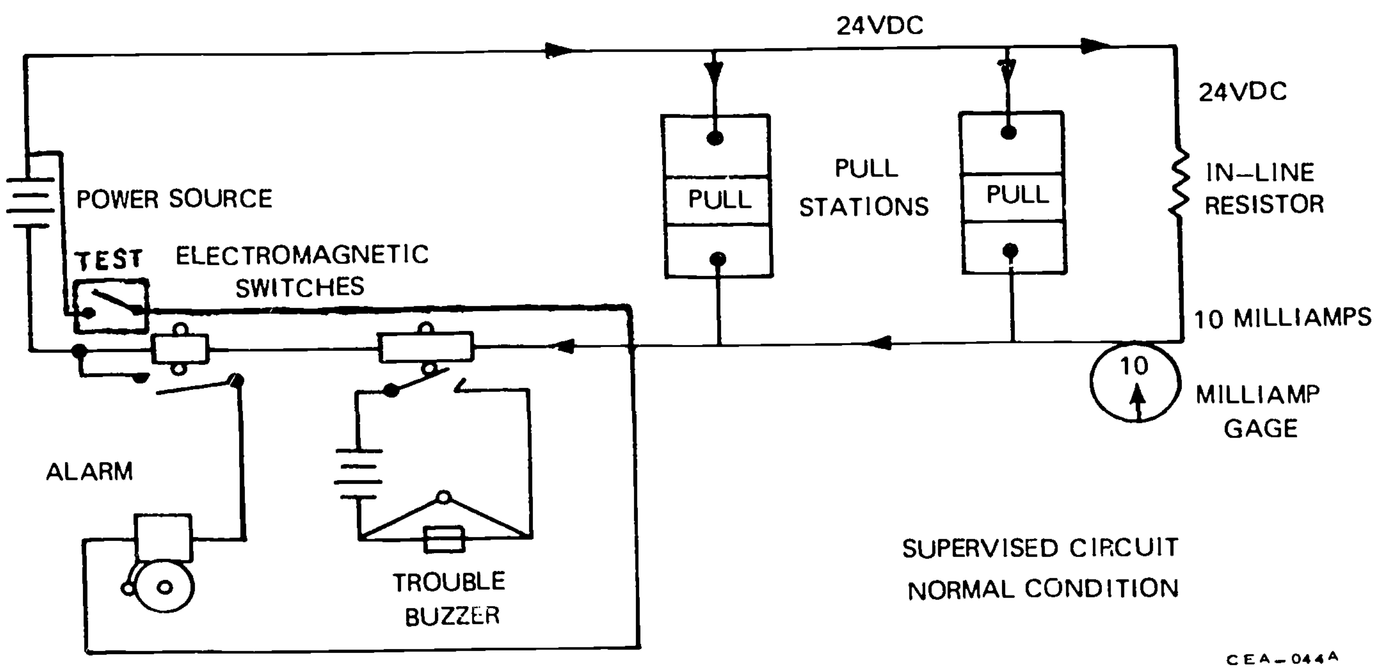



Figure 5–3. Alarm system with test circuit.

are normally open but close when activated, completing the alarm circuit.

The closed-type detector works on the principle of the supervisory circuit. A balanced milliamp current flows through the detector contacts. When the detector activates, the contacts open, breaking current flow through the circuit. However, instead of a trouble signal, a fire signal is activated.

**Exercises (452):**

1. What are the basic components of a manual fire alarm system?

2. What is the operating principle of a manual alarm system?

3. Why would you install a supervised alarm system?

4. What operates the trouble buzzer in a supervised alarm circuit when AC power fails?

5. What function does the test switch serve in an alarm system?

6. What is the operating principle of an automatic alarm system?

7. Automatic detectors are basically what type of electrical component?

8. What happens to the contacts, on a closed type detector, when it activates?

**453. Restate specific details of installation, maintenance, and repair of fire alarm systems.**

**Installation and Connection Procedures.** The following general guidelines will help you to install and connect a fire protection system.

*a*. All systems shall be installed in a workmanlike manner and in accordance with the specifications and standards approved by the major command.

*b*. At the request of the major command, complete information regarding the system, including specifications, wiring diagrams and floor plans, shall be submitted for approval prior to installation of equipment or wiring.

*c*. All inside wiring shall conform with the requirements of the National Electrical Code (Article 725) for class 1 signal systems. Flexible cords described in Article 400 shall NOT be used.

*d*. Cable operating at 150 volts or less, shall be solid copper conductors, not less than No. 14 AWG for single- and two-conductor cables, not less than No. 18 AWG for three- and four-conductor cables, and not less than No. 22 AWG for cables having more than four conductors.

*e*. Cable may be installed exposed or concealed in a ceiling and in a side wall if not less than 7 feet from the floor and protected from injury. Cable installed less than 7 feet from the floor shall be installed in conduit or other approved raceway.

*f*. The power supply circuit shall be connected on the line side of the main service and have a means of disconnect.

*g*. No other circuits except those specified are to be connected to fire alarm circuits.

*h*. All wiring for fire alarms will be kept entirely independent of regular building wiring. Separate raceways, conduits and boxes will be provided for fire alarm circuits only.

*i*. Equipment should be designed and installed to prevent tampering. Pull stations shall be mounted at every outdoor exit, a minimum of 4½ feet from the floor.

**Installing Detectors.** The installation of detectors, when total coverage is required, shall include all rooms, halls, storage areas, basements, attics, lofts, spaces above suspended ceilings, inside closets, elevator shafts, inclosed stairways, and accessible under-floor spaces.

When you begin installing the detectors, they must be supported by a box or fitting independent of the circuit conductors. NEVER recess a detector in any way into the mounting surface.

The alarm circuits should be color coded for maintenance and troubleshooting. All accessible connections should be soldered to prevent potential opens.

The remainder of the installation and connection procedures, for your alarm circuits, are the same as for any other electrical circuits.

For additional information as to where to install a fire alarm system, consult Chapter 13 of AFM 88–15, *Air Force Design Manual—Criteria and Standards for Air Force Construction*. The installation instructions are found in AFM 91–37, *Maintenance of Fire Protection Systems*.

**Inspection and Maintenance Procedures.** The schedule for inspecting and testing installed fire protection systems is outlined in AFR 92–1, *Fire Protection Program*, Chapter 2. The inspection and maintenance performed by CE Shops are included in the appropriate recurring maintenance program as outlined in chapter 5 of AFR 85–1.

Installed fire protection systems require the coordinated actions of civil engineering shop crafts personnel and fire-protection specialists if they are to be properly inspected, tested, and maintained. Each base develops a civil engineering operating instruction that directs the actions necessary to insure system reliability.

Because of the variations in equipment from different manufacturers and the numerous types of circuits and devices installed, specifically in overseas areas where systems have been installed by the host country, it is important to have the following reference materials available: wiring and equipment schematic diagrams, as built drawings, and manufacturers' technical data and system revision information. Reference materials should be maintained in the technical services section.

**General Maintenance.** General maintenance procedures include periodic testing, cleaning, and adjustment. When performing tests which cause sounding of audible and/or visual signals, inform the building occupants of your actions to prevent possible panic.

Your shop maintenance action sheets may have the following items listed for periodic maintenance:

(1) Check primary power for ± 10 percent deviation.
(2) Check secondary power supply at the rectifier.
(3) Inspect and clean batteries and terminals.
(4) Perform random sample operation of pull stations and detector heads.
(5) Secure all equipment and terminals to normal operation.

You can see by this list that maintenance is primarily a visual and operational check. Your installed systems may require further actions.

*Troubleshooting.* Most manufacturers provide detailed installation and setup procedures for their equipment. A few voltage readings at the control panel should pinpoint the trouble. The most frequent problems occur at the wire terminations, by corrosion or broken conductors. The termination points are in the control cabinet, at the detectors, and at the indicating or sounding devices. These are the points where wires are usually disconnected for testing or replacing defective equipment. The wires can be damaged in reconnecting to the terminals.

Most automatic alarm systems are installed in LOOPS. A loop is an alarm circuit installed in a portion of the building under protection. Normally, each loop will also have a corresponding lamp on the control cabinet door. Take a three-story building as an example. A loop may be installed for each floor. Or it may be installed in one half of each floor. This serves two major purposes. First, the firefighters can tell what portion of the building the alarm was transmitted from. Second, it also helps us, the electricians, in troubleshooting when a fault develops in the system. Remember, the only troubles possible are OPENS, SHORTS, or GROUNDS.

We have covered troubleshooting in previous chapters; however, one thing unique to an alarm circuit is the loop. Once you determine which loop is defective, you can troubleshoot it very easily. Break the circuit electrically in half. That means if there are 20 detectors installed on the LOOP, open the circuit at the eleventh detector and use meters to check back to the control unit and forward to the end of the loop. One reading should be good, and the other will show the fault. Then, split the faulty portion in the center again. You should eventually eliminate good wiring and pinpoint the bad device or piece of cable.

*Repair and replacement.* Fire alarm detectors are normally sealed units and not repairable. They should be disposed of properly or packaged and shipped back to the manufacturer. Replace detectors with the same type of detector removed.

Wire can be replaced by using the defective conductors as a pull wire. ALWAYS tag any conductors disconnected for troubleshooting or repair.

When the fault is located and repaired, reconnect all wires and test the system by actuating an initiating device. Inform the base fire department when the alarm system is restored to service.

**Exercises (453):**

1. Who has the final approval authority for installation of a fire alarm system?

2. Single cables operating at 150 volts shall be what minimum size?

3. Cable installed less than 7 feet from the floor must be installed in ____________ or approved ____________.

4. The power supply must be connected to the ____________ side of the main service.

5. Pull stations must be mounted ____________ feet from the floor.

6. Never ____________ a detector in any way into the mounting surface.

7. Alarm circuits should be color-coded for ____________ and ____________.

8. What Air Force regulation gives a schedule for inspecting and testing installed fire alarms?

9. What reference materials should be available when inspecting and testing installed fire alarms?

10. Maintenance of fire alarms is primarily a ________ and ____________ check.

11. Where do the most frequent problems occur in fire alarm wiring?

12. What is one method of troubleshooting a fire alarm LOOP?

13. What kind of replacement is required for faulty detectors?

## 5-2. Intrusion Alarms

So many types of intrusion alarm systems or combination systems are available today that a detailed discussion here would not be practical. All alarm systems are of a special nature, and no two systems will ever be identical.

We will cover one intrusion system developed to be used by all branches of the service. This system is called Joint Services Interior Intrusion Detection System (JSIIDS). The system has been designed to protect small arms, ammunition, and sensitive materials in storage.

### 454. Restate information pertaining to the purpose and components of JSIIDS.

**Purpose.** JSIIDS was designed to detect, not prevent an attempted intrusion. The main purpose of JSIIDS, or any alarm, is to give the earliest possible notice of an attempted intrusion. The more notice the reaction force (Security Police) has before the intruder gets past the outer boundaries, the better the chance that the intruders will be caught.

**Components.** The various components of JSIIDS are two general classes, the control unit and its sensor components and the monitor and display equipment.

*Control unit.* The control unit is the central control element of the JSIIDS. It is located within the protected area. It receives and processes the intrusion tamper and duress alarm signals generated at the sensors.

The control unit contains an emergency standby (battery) power supply with an automatic switchover when primary AC power is lost. It operates in much the same manner as the emergency lights discussed earlier.

The JSIIDS mode of operation is controlled by a key switch mounted on the control unit door. Three modes of operation are provided.

(1) Secure—when the protected area is not open to authorized personnel. In this mode all alarms are processed.

(2) Access—when the area is open to authorized personnel. In this mode, only tamper and duress alarms are processed.

(3) Test/Reset—when electricians like us perform tests and maintenance. All alarms are processed, and a sounding device operates for 10 seconds at the control unit to aid in testing.

*Sensor.* There are four classes of sensor components associated with the control unit. They are classified as:

(1) Penetration sensors—those designed to detect penetration into the protected area, through doors, windows, walls, floors, ceilings and other openings in the room.

(2) Motion sensors—those designed to detect movement of a person within the protected area.

(3) Point sensors—those designed to detect the attempted removal of an item from its normal position in the protected area, like a rifle from a weapons rack.

(4) Duress sensor—those designed to be activated by guard personnel to call for help under a duress situation.

*Monitor cabinet.* The monitoring and display equipment is the primary notification equipment of the JSIIDS. The monitor cabinet has a self-contained signal module and primary and emergency power supply. The signal module displays the status of the monitor cabinet power supply; that is, operation on the primary or emergency power source.

*Display equipment.* The display equipment is located in an area where monitoring personnel are on duty 24 hours a day. The monitoring equipment consists of a status module or an alarm module, one for each control unit.

Status monitor module. The status monitor module displays the status and mode of operation of one control unit. By looking at the lights on the status monitor module, the monitoring personnel can tell what is taking place in the protected structure.

Alarm monitor module. The alarm monitor module is used in the monitor cabinets when only an alarm indication is required.

**Exercises (454):**

1. What is the main purpose of any intrusion alarm?

2. What are the two general classes of JSIIDS components?

3. Where is the control unit installed?

4. What happens when primary power is lost to the control unit?

5. Name the three modes of operation of a JSIIDS.

6. What control unit sensor is designed to detect movement within the protected area?

7. What does the signal module in the monitoring cabinet display?

8. What monitor module is used in the monitoring cabinet to display mode changes in the protected area?

**455. Give specific details about the operation, installation, and connection of the JSIIDS.**

**Theory of Operation.** JSIIDS operates on the basic theory of a 20-volt DC circuit, with less than 2,000 ohm resistance being supplied to the detector or detector processors. This voltage is provided from the control unit. A rise in ohmic value of the circuit to 100 thousand ohms will trigger an alarm or tamper condition in the control unit.

If you think about that for just a minute, isn't that the way our supervised fire alarm circuit operated? Sure it is! One main point to remember in any alarm system is that a small change in current flow (less than one-tenth of an amp) can be used to activate an alarm. Our basic Ohm's law proved that a rise in resistance will cause a drop in amperage in the same circuit.

When the control cabinet receives an alarm or tamper signal, it then transmits the signal over telephone lines to the monitor cabinet.

**Installation.** The installation of components of the JSIIDS must comply with the current edition of the National Electrical Code (NFPA No. 70) and with the following requirements for mounting, conduits, and conductors.

*Component mounting.* Wall-mounted components are designed to be held by fasteners that are accessible only through the open door or cover of the component. Conduit holes should be cut in the inclosure before it is mounted if they are not already provided. All holes should be made with a 1/2-inch chassis punch. NEVER use a hole saw, since it produces metal shavings that can harm the performance of the equipment.

*Conduit.* All conductors except phone lines outside the protected area will be installed in rigid galvanized steel conduit or intermediate metal conduit in accordance with article 345 of the NEC. Conduit outlet boxes, pull boxes, junction boxes, conduit fittings and similar inclosures shall be cast metal or malleable metal, with threaded hubs or bodies. Conduit for JSIIDS circuits shall contain no building wiring.

Minimum size conduit shall be 1/2 inch. All requirements for tapered threads, supports, bends, locknuts, and bushings are the same as discussed under hazardous wiring.

Covers on pull and junction boxes used in installation o the system will have a tamper switch installed, or be tack welded, brazed, or filled with epoxy, or provided with twist off screws.

*Interior conductors.* Power conductors for 120-VAC power to control units and monitor cabinets shall be solid copper no smaller than No. 14 AWG, type RW or RH–RW or THW insulation.

Low-voltage conductors shall be no smaller than No. 22 AWG. They shall be installed using crimp-on spade terminal lugs at all wire connections to threaded screws on component terminal boards.

All neutral conductors and noncurrent-carrying metal parts of equipment will be grounded.

A wiring diagram of the installed system will be drawn up for each protected area. The diagram should indicate which sensors are installed and show color-coded interconnections between each sensor and the control unit. The diagram will aid in maintenance and troubleshooting. The diagram should be classified confidential and placed in an appropriate security container.

*Connection.* All installation requirements and component connections for the JSIIDS are found in the Technical Order series 3159–4. Foldouts are provided in block diagrams for each component used by the JSIIDS. One point you should remember is that JSIIDS components are manufactured by several manufacturers using Government specifications. Always check the terminal boards before connecting your conductors. One system may have the terminals numbered from left to right, but the next system you install may be numbered from right to left. Always check before you connect.

**Exercises (455):**

1. What is the normal NO ALARM voltage of a JSIIDS circuit to the detectors?

2. What causes an ALARM condition?

3. Why should you never use a hole saw when installing JSIIDS equipment?

4. What are the requirements for securing covers on pull and junction boxes used in installing the system?

5. What are the smallest conductors allowed for 120-VAC power and low-voltage circuits, respectively?

6. What are the requirements of the diagram made for an installed system?

7. What is the technical order series that covers the installation and connection for the JSIIDS?

**456. Restate information pertaining to the maintenance, troubleshooting, and repair of the JSIIDS.**

**Maintenance.** The JSIIDS should be inspected on a monthly basis as part of your shop's recurring maintenance program. Always inform the reaction force or law enforcement desk before you begin. The system is vulnerable to compromise during maintenance, and for this reason, the alarm crew should request a security person to accompany them for their own protection. You should alter the schedule of your inspections with a different routine each month.

General maintenance of the JSIIDS includes a visual inspection of all equipment, conduits, and boxes. Look for signs of tampering, loose straps, or screws and observe the general condition of flexible cords or conduits.

Perform an operational test of all installed sensors, check the power supply for proper voltages, and check the condition of the battery. Return all functions of the system to normal operation and call the law enforcement desk before leaving.

Maintenance procedures for the control unit and each sensor component are listed separately in the T.O. series 3159–4.

**Troubleshooting.** The JSIIDS was designed for fast, easy troubleshooting. Inside the control unit is a component called the status processor.

Mounted inside the processor are printed circuitboards (PCB). There is one PCB for the duress switches and one for each group of additional sensors. This means that the group of motion sensors terminate to one PCB, the door co ts to another PCB, and so on. Installed in the last PCL are light emitting diodes (LED). The LED looks like a small red lamp that illuminates when the processor rec ves the initial alarm input. The LED will remain illuminated until the system is reset.

When you open the control unit door, you can see immediately what sensor group triggered an alarm by checking for an illuminated LED.

Each PCB has test points for a voltmeter. The status of each sensor group can be checked at these test points for a tamper or alarm condition. An alarm condition will give a 20-VDC reading. When the problem is cleared and the system is reset, the voltage should drop off to zero.

Most system malfunctions and troubles will come from a faulty power supply. The JSIIDS requires a constant 20 VDC ± 1 volt to operate. When the power supply starts breaking down, the voltage will start creeping up or down. A voltage reading of less than 19 VDC or more than 21 VDC requires the replacement of the power supply.

A complete troubleshooting chart of the control unit and individual sensors is available in the T.O. series 3159–4.

**Repair.** The major JSIIDS components are designed in modules. Repairs to the system are normally made by replacing the defective module. An example is the power supply. It can be replaced after disconnecting and tagging all conductors and removing four screws. The status processor can also be replaced by removing four screws, or a single PCB in the processor can be replaced by a snap and pull action. The new PCB is then inserted back into the processor.

Minor repairs can be completed with the aid of a soldering gun. These components are toggle switches, fuse holders, the mode switch, and so on.

Your main concern is to repair the system as soon as possible and bring it back on-line. The defective components can then be shipped back to depot for replacement.

The main point to remember when replacing JSIIDS components is to TAG YOUR CONDUCTORS. One conductor out of place can cause you hours of downtime troubleshooting.

**Exercises (456):**

1. Why should the alarm crew alter their maintenance schedule each month?

2. What T.O. series cover maintenance procedures?

3. What is the purpose of the light-emitting diodes inside the status processor?

4. What voltage reading should you have on the PCB test points for an alarm condition? For no alarm?

5. What are the minimum and maximum voltages allowed from the power supply before it must be replaced?

6. Repairs to the major components are normally made by what action?

7. What is your main concern when repairing the system?

8. What is the main point to remember when replacing JSIIDS components?

# Contingency Responsibilities

DURING YOUR past experience in the Air Force, your primary concern has only been yourself and your relationship to the job at hand. As you progress in the Air Force, your responsibilities will also increase. How you accept these additional responsibilities will affect not only you but the people around you. The ability to get the job done under difficult situations sometimes has less to do with the skill to do it than the attitudes toward the job at hand. As you progress, you will be responsible for the workers that you supervise as well as for your own personal performance. In some contingency operations you may be the senior man, with the outcome of the situation resting squarely on your ability to get the job done. Getting the job done will depend on keeping your people safe, well, and in good spirits, as the situation permits. They must believe in you, trust you, and follow your directions. They are going to look to you as an example both on and off the job. It is a difficult task. How well you accomplish it will have a definite effect on getting the job done right and on time as well as bringing your people through.

## 6-1. Field Sanitation and Hygiene

In field conditions, field sanitation control and personal hygiene are going to be very important in maintaining the health of the work force. It is an established fact that most lost time under field conditions is due to illness caused by stomach problems and parasites. Most stomach illnesses can be traced to poor field sanitation situations, while most parasite problems can be traced to poor personal hygiene. Control of disease and pestilence can be traced directly to the thought and care given to field sanitation and personal hygiene.

**457. Differentiate between acceptable and unacceptable field sanitation methods.**

**Waste Disposal.** While the particular situation will dictate what method of field sanitation is used to dispose of waste, the prime factor is to make sure that all waste is properly disposed of. Early stages of the operation may require primitive methods of disposal; but, seeing that disposal is made is very important. Empty ration cans, wrappings, and other such litter that is left about not only serves as a food supply and breeding ground for pests but also can give away your position to the enemy. Bury litter to protect yourself two ways. Make sure that your people understand and comply with proper waste disposal methods. For a small contingent of personnel, a simple pit where waste food and containers can be deposited will be sufficient. If the garbage is covered with a layer of dirt after use, then pests are denied a breeding place and food supply, and the area is kept clear of debris. With larger groups, incineration as well as burial may be the best method.

Human waste must likewise be properly disposed of. Care in site selection must be used. Normally this site selection will be the responsibility of the medical or veterinary section of the contingent. They will also determine the type and capacity of the facilities that are required. Your job is to see that the facilities provided for proper human waste disposal are used by all hands. Failure to enforce proper disposal will result in a potential disease situation. Many stomach problems are related directly to human waste disposal. Loss of personnel to sickness means either a failure to complete assigned tasks or that the remaining personnel are going to have to work longer hours to make up for people who are not available. Since it will be your job to see that the job is completed on schedule, it is in your best interest to see that your people do not take chances that can result in their being ineffective

**Personal Hygiene.** Equally important to field sanitation are facilities that can provide for maintaining personal hygiene of the participants. This equipment can be improvised to provide showers, hand washers, or shaving facilities from barrels, helmets, and scrap lumber. See figures 6-1 and 6-2. It is imperative that proper water quality be maintained and used. Impure water carries a multitude of problems. Be sure that the improvised materials used are clean and free of rust or other contaminants. Good water can become polluted by poor sanitary measures used in its transportation or distribution. Remember that lack of water intake can cause dehydration in any climate, hot or cold. A rule of thumb for temperate climates is 5 gallons of water per day per man for drinking and cooking.

**Exercises (457):**

Identify acceptable field sanitation practices by placing an X in the space provided.

_____ 1. In early contingency stages, refuse can be buried.

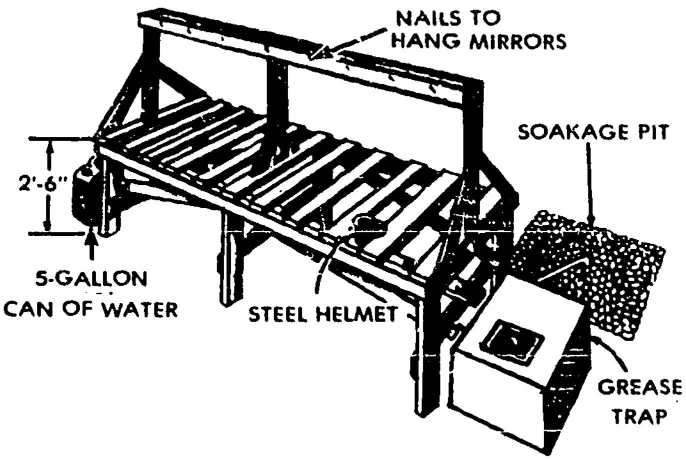
_____ 2. Garbage disposal can be left to the environmental control specialists.

_____ 3. Waste disposal sites should be selected by the medical or veterinary personnel.

_____ 4. Water is safe as long as it is clear and running.

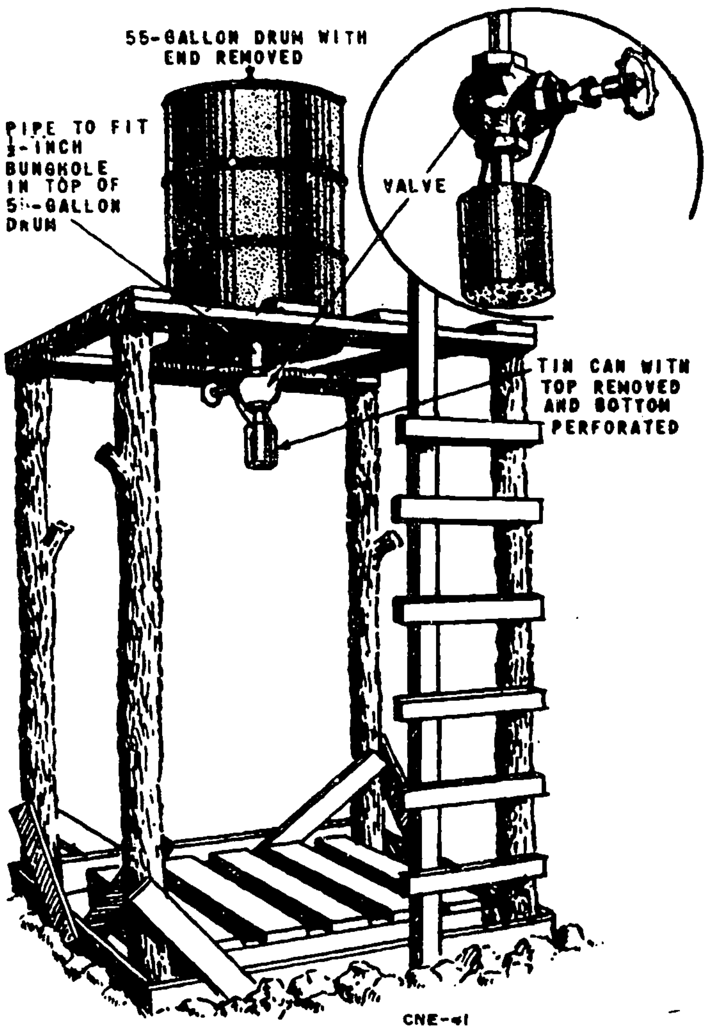
_____ 5. It is not necessary to purify water used for bathing.

_____ 6. Human waste is responsible for many stomach problems.




Shaving and washing device. CNE-40

Figure 6–1. Shaving and washing device.




*Mounted inverted drum shower.*

Figure 6–2. Mounted inverted drum shower.

**458. Identify factors involved in the personal well-being of individuals during contingency operations.**

Many factors will be involved in the well-being of people in a contingency situation. These factors will include personal hygiene, foot care, diet, exercise, and mental condition. We will cover these factors one by one.

**Personal Hygiene.** Since most contingency operations are going to create a large amount of dust, dirt, and sweat, personal cleanliness will be a factor. The chance to clean up after a day of hard work is something that most people look forward to. If facilities are readily available, most individuals will avail themselves of the opportunity to clean up and put on fresh clothes, but the more energy and innovation required to do this, the less likely individuals are to make the effort.

Although proper advice and instructions have been given by medical and dental personnel, some people will ignore the warnings, claiming they are "too tired" or "not feeling good." These few can make life miserable for everyone. Try to get them straightened out as quickly as possible to reduce the possibility of their infecting the whole group, both mentally and physically.

**Mental Attitudes.** Good mental attitudes among all personnel are of vital importance to the success of this type of unusual situation. It requires the best of all members of the group as far as getting the job completed on time. One or two members who do not pull their fair share of the load will affect the whole group in two ways. First, the other members must do the work of these "free loaders" and will, therefore, give up the rest they should have. The second factor is even more important: seeing that these members are not doing their fair share of the work will have a detrimental morale effect on the members who are contributing to the success of the mission. This will cause a letdown of all members and a general breakdown in efficiency.

"Firm but fair" should be your guideline in dealing with this situation. What people are capable of doing has a lot more to do with their mental attitude than with their physical condition. It is very seldom that people are pushed to their physical limits. Their abilities to perform and survive are far greater than most of them would believe. More will quit because of mental fatigue than because of physical fatigue. Part of your job will be to stress the importance of the operation and to reiterate its importance and progress from time to time. Realize that people's attention is divided by tension, stress, discomfort, fear, and fatigue and may wander from the prime mission at hand. Let know how they are doing. Set them an example, and most of them will surprise you with their ability to perform.

**Foot Care.** Foot care must begin, if at all possible, well before the contingency operation begins. Foot care and footwear go hand in hand. Improper footwear, either because of fit or type, will cause foot problems.

The foot wear selected for wear during this type of exercise must be sturdy enough to stand the wear, worn enough to be comfortable during long hours on your feet, and the proper type for the climatic conditions in which you will be working. It must protect your feet without binding, rubbing, or chafing. Blisters or corns and calluses can

develop very rapidly when a person is on his feet for long periods. If the boots and socks become wet, the likelihood of foot trouble is increased. Should mud, dirt, or sand enter the boots or shoes there is a possibility of more serious foot trouble.

Remind your people of ways to protect their feet: clean socks, dry shoes, and foot massage are factors that will reduce foot trouble. Proper and early attention to protect blisters or chafing is important. Additional protection by use of Band-Aids or pads will prevent further damage. Long periods where feet are wet can result in trench or immersion foot. Under certain situations and conditions, trench foot can totally disable an individual. Foot massage and dry footwear are the best methods of reducing or preventing this condition. Even if dry shoes are not available, foot massage and dry socks on a daily basis will normally retard the onset of this condition. You should stress these facts to your people prior to and during contingency operations.

**Diet.** It would be wise to forego food prepared by the local populace for several reasons. First, in terms of this country's standards, the sanitary conditions under which the food is grown and prepared in most foreign countries leaves something to be desired. Second, by the stress under which you will be working is not conducive to normal digestion. Thirdly, spices and seasonings, as well as other ingredients, used in foreign dishes can cause digestion problems. Combine all of these factors and your people can be incapacitated just as effectively by stomach upsets as they can by enemy fire.

It is important that all hands receive proper nourishment during periods of great activity. While field rations will never be mistaken for good home cooking, they will provide all the nourishment that you require if you eat them. You should remember that all the extra exertion that you will be using is going to cause extra sweat and, therefore, a loss of body minerals. Extra salt with your food will help to replace salt that is lost through sweating.

Contaminated or dirty eating utensils are a major source of infection. Extra care should be taken in scrubbing and sterilizing mess kits. Kits should be cleaned, washed in soapy water, rinsed in hot water, then dipped in clear, boiling water to sterilize them.

**Exercise.** Most of your people will get plenty of exercise during the early stages of a contingency operation, since establishing perimeters, digging defensive positions, setting up camps, and performing job specialties will require all their time. During this time sore muscles, bruises, and strains will be common because of the different and more strenuous activities that these workers will be doing. As the situation stabilizes and activities reduce in intensity, a program of exercise and recreation will need to be developed to take up some of the spare time and to provide an alternate source for burning excess energy. Some members of the group will be interested in team sports, while others will not. All members should participate in some form or organized exercise program for their own health and well-being. Insist that all participate in some form of exercise and not spend excessive time alone or apart from the group. This can lead to poor mental health from having too much time to brood on their particular situation.

**Mental Condition.** Probably the most difficult of all factors to control is the mental state of the individuals involved in an unusual situation. Since each person in the group has had different experiences, different environments, and different relationships, each response to the same stimuli will most likely be different. To maintain an effective force you must, to a certain extent, maintain an effective state of mind in the group.

Several factors will be involved in maintaining this state of mind of the group. Each factor is important but not necessarily of equal importance to each individual. The first of these factors is training. If individuals know their jobs and all aspects of these jobs, they will have less apprehension and stress in doing the jobs as required.

The second factor is information. Provide information, both good and bad, to the team as you receive it. If individuals feel informed, they feel more competent to handle whatever comes. They will feel more confident in the leaders of the exercise and the overall probability of success if they are informed. Surprises and confusion as to what is required are causes of apprehension and stress.

A third factor toward mental well-being is a team spirit. If the group as a whole believes in the group as individuals, the chances for success are greatly increased. The success of the team as a whole then becomes of greater importance than the individual comforts. Quite often a situation that has gone sour will be rescued by great individual efforts in the name of the group. Try to develop pride in the accomplishments of the group.

Another factor is your ability to listen and counsel individuals as the situation requires. The ability to go one-on-one with your workers and to see their point of view while keeping the mission in focus and resolving the problem so that all concerned are left in a tolerable situation is the mark of a good supervisor. This requires an ability to listen, analyze, empathize, summarize, and reach acceptable solutions to varied problems. If you are able to do this, you will have workers who will move mountains when the time comes. The statement, "Praise in public, counsel in private" should be a guidepost on every supervisor's road to the proper frame of mind for each person with whom the supervisor has contact.

**Exercises (458):**

Complete the following statements that concern the personal well-being of individuals during contingency operations.

1. Proper dental advice and instructions will be provided by ____________ and ____________ personnel.
2. Stress, fatigue, and tension will affect the ____________ condition of an individual more than his or her ____________ condition.
3. Footwear selected for a contingency operation should be selected for the climatic conditions involved and should be well ____________ ____________.
4. Two factors that will reduce the chance of trench foot are ____________ and foot ____________.

5. To replace minerals lost through sweating add extra ____________ to your food.
6. All members should engage in a regular program of ____________ when possible.
7. The first factor involved in the proper mental condition of your people is ____________.

## 6-2. Self-protection from Extreme Weather

Because of the commitments of the United States, you must be prepared for a contingency operation anywhere on earth. This means that you must be able to operate and survive in any type of extreme weather condition. In order to do this, you must understand the conditions and effects of extreme weather.

**459. Identify factors pertaining to protection from extreme weather.**

**Desert Conditions.** Usually, one thinks of sand dunes and camels when one hears the term "desert." While this picture is correct in a very limited degree, the usual desert is more likely to be one of rock and scrub vegetation. It is mostly rock because the top soil has been carried away by wind due to a lack of surface moisture, and it is scrub for the same reasons. Because of this lack of moisture, temperatures are extreme. While days are very hot, nights are very cold. Weather changes tend to be sudden and violent. Rain, when it falls, causes sudden flooding because no topsoil or vegetation is available to hold or slow the runoff. Sites can become quagmires where no equipment can move until the water dries up. While rains are rare, they can halt work very effectively.

Normally, humidity will be very low in desert areas and personnel will not notice the large amounts of body fluids that they lose, because sweat will evaporate so rapidly. Dehydration is a real and ever-present danger. Make sure that individuals are provided with sufficient water as well as salt to replace salt loss due to sweat.

Wear proper and adequate clothing. Head covering is very important in preventing sun related health problems such as sunstroke and heat exhaustion. While some members will wish to work without shirts and/or in shorts, this is not a good idea. Outer garments will collect sweat, which will aid in body cooling and also prevent sunburn. Shoes should be sturdy to protect the feet from rocks and thorny growths.

Most vegetation will be hard, stiff, and protected by spines of other projections. Most reptiles and a large percentage of the insects of these regions will be poisonous. Take extra care to shake out clothing and footwear before dressing each morning, as scorpions will get into them at night seeking warmth. Do not neglect any type of insect bite or sting. Both domestic and wild animals are sources of parasites and should be avoided. If you expect to be out after sunset, carry extra clothing, since the temperature will drop rapidly.

**Jungle Conditions.** Basically, there are two types of jungle terrain. These are the mountainous rain forest and the lowland or coastal types. In both cases, your problems will center on an overabundance of moisture and vegetation. Trying to cope with these two things is almost a full time job.

Vegetation grows rapidly, continually, and prolifically. It must be constantly controlled and disposed of. When the vegetation is removed, you have mud. The constant moisture rusts equipment, rots cloth, and mildews leather. The vegetation and moisture combine to provide a perfect breeding ground for insects, reptiles, and rodents. Parasites are found in large quantities. Cuts, blisters, or scrapes are difficult to heal and have a tendency to become infected. Heat and humidity, along with insects, make rest difficult to obtain. Personnel often do not eat properly and, strange as it may seem in all the moisture, often become dehydrated. As a supervisor you will be taken to your limits to get the work out, keep your people well, and help them keep up their morale.

Frequent rest periods are necessary due to the heat and humidity. Extra salt is required because of excessive sweating. Good personal hygiene will reduce the likelihood of lost time due to illnesses.

**Cold Climates.** Cold climates create special problems in the areas of tools, personnel protection, and equipment. In addition, extreme conditions of blizzards or ice fogs (white out) can immobilize a project for extended periods. Survival can become a fulltime occupation under these conditions.

Clothing is of primary consideration. Layers of clothing are preferred over single, bulky garments. Particular attention must be paid to hands, feet, and head as far as protection is concerned. Glove liners need to be worn with mittens. Footwear needs to be made up of layers of clothing and should not bind or restrict circulation. Socks that become damp with perspiration need to be changed at the first opportunity. All clothing should be loose enough to allow for circulation of air to carry away perspiration. Head covering is very important, not only to reduce the possibility of freezing ears, nose, or cheeks, but also to reduce the body heat loss from the head.

Tools and equipment pose special problems in extremely cold weather. Steel becomes brittle, lubricants become solids, tolerances change, and contractions of metals break joints and welds. Bare skin can freeze instantly to cold metal with disastrous results.

Advise your people of the pitfalls of cold climates prior to deployment. Observe them closely during periods of activity. Institute a "buddy system" so that they will watch each other for evidences of frostbite or other dangers attributable to cold climate operation.

Should the contingency operation take place during the summer months of the arctic season, other problems will arise. Insects become a major problem during this period. Mosquitoes, black gnats, and deer flies, all blood feeders, abound in this area and can become very dangerous to an unprotected person. Check the headnets, gloves, and insect repellant of all members before they are sent out. Excess water and mud are another summer problem. Trench or immersion foot can develop during this period. Foot care and massage should be emphasized. During both the summer and the winter seasons in arctic areas dehydration is likely.

**Exercises (459):**

Mark the correct statements with an X in the space provided and change the incorrect statements so that they are correct.

_____ 1. A desert is most likely to be made up of sand.

_____ 2. Desert nights are cold.

_____ 3. Head covering in the desert will help prevent sunstroke.

_____ 4. Desert footwear should be thin and soft.

_____ 5. There are two basic types of jungle.

_____ 6. Jungle moisture will not affect equipment.

_____ 7. One danger in a jungle environment is dehydration.

_____ 8. In an arctic condition, several layers of clothing are better than one bulky outer garment.

_____ 9. In a cold climate, footwear should fit snugly.

_____ 10. Blood-feeding insects will be present in arctic winter seasons.

_____ 11. A "buddy system" is used so that each person can watch the other for early signs of frostbite.

_____ 12. Trench foot will be a health hazard in arctic winters.

## 6-3. Work Party Security

The worldwide commitments, plus the many different types of contingency operations that you may be involved with, make it difficult to set up hard and fast rules for work party security. Some basic rules that apply to most situations deal with cover and concealment, fire discipline, offensive and defensive positions, and communications. While you will not be expected to be a trained infantryman, you should have a basic understanding of military tactics necessary for you to help with your own work party security.

**460. Identify proper work party security techniques.**

**Cover and Concealment.** Cover and concealment are necessary, whether on offense or defense. When moving on an assault or sweeping action, use natural cover and concealment such as brush, ditches, trees, or grass to break up your outline or to protect you from flat trajectory fire. When using grass as cover, do not move in a straight line, since the movement of the grass could easily give your position away. When possible, try to move or change positions during times of distraction such as wind, rain, dust, or any such period when the enemy might be distracted by outside forces. Move in short rushes, picking out your next point before you leave the cover where you are. Stay away from ridge lines, open spaces in woods or fields, and other areas that can outline you as an open target. Stay low and look through or around brush or obstructions. Avoid unnecessary movement. Never come out of cover at the same place you went in.

From a defensive position, use natural material for cover. Grass, brush, trees, or rock will break up your outline. Shadows provide good cover. Try to avoid symmetrical patterns when constructing parapets or firing points and foxholes. Use brush and rocks to break up outlines. Avoid leaving raw earth or dead camouflage brush around the defensive position. You should also keep the area policed up of ration cans, cigarette butts, paper, or any material that can draw attention to or give away the position. Keep movement to an absolute minimum. Movement is the easiest thing to spot. You can move your eyes without moving your head.

*Offensive positions.* Fighting holes differ quite a bit between offense and defense. When moving on offense, you will use mostly natural depressions, ditches, rocks, and trees as protection. Should a fire fight develop, a skirmishers' trench can be quickly constructed. This is a low trench in which the dirt removed from the trench is piled between you and the enemy. This provides a fighting hole that provides protection from low-trajectory fire.

*Defensive positions.* Defensive positions may start from the skirmishers' trench but should be developed as quickly as possible to the foxhole. The foxhole is the basic defensive fighting point. Normally, the foxhole will be developed as a two-man fighting position and, as time and materials permit, will be developed to a covered bunker, complete with firing slits and cleared field of fire.

**Communications.** Battle area communications are very important for two reasons. First, all members of the team need to know what is going on in order to provide a concentrated effort when needed. The second reason concerns morale. In this type of high-stress situation, not knowing what is going on will create fears, doubts, and possible panic. This will also lead to mistakes, poor fire discipline, and further breakdown of communications.

As the leader of a group, it is your job to see that every member "gets the word." Know and practice hand signals to be used. Know the type of electrocommunication equipment available and its operation. Position yourself so that you can relay instructions rapidly and accurately to your people. Assure that your people know the signs and countersigns and passwords for each time frame.

**Fire Discipline.** Nothing gives away inexperienced troops as quickly as poor fire discipline. Stress the fact that targets must be identified. Indiscriminate firing of weapons will not only give away positions and numbers but will do little to no damage against seasoned troops. Firing without specific orders may warn and allow enemy troops to escape a well conceived trap. Only in the case of an all-out assault by large numbers of enemy should individuals fire without specific orders. This should happen only after the enemy has passed a predetermined "fire at will" point. Even at this point the fire should be controlled. Aim fire where the target is identified and each round expended is delivered on target. Volume automatic fire is generally ineffective unless delivered on troop concentrations or vehicles.

The normal fire command will be given in a certain sequence that will alert the people involved, give the general direction, a specific point if applicable, the specific type of target, the range in meters, the type and amount of fire; and the command. An example of a fire command would be:

Squad (number of people to deliver fire).
Right front (general direction).
Red barn (reference).
Right corner (specific reference).
Automatic rifle (specific target).
Two zero five (range in meters).
Three rounds (type and amount of fire).
On my command (when to fire).
Fire (deliver fire on target).

This type of fire control is then capable of delivering a concentration of fire on a specific target. Fire discipline is the result of much practice.

All facets of work party security must be coordinated. No one part is sufficient into itself.

**Exercises (460):**

1. Place an X by those statements that identify proper work party security techniques.

_____ a. When on patrol, keep to the open spaces.
_____ b. When establishing a defensive position, use natural terrain features to break up outlines when possible.
_____ c. Automatic fire is more effective than semiautomatic fire.
_____ d. Trash and litter can give away a defensive position.
_____ e. Normally, defensive foxholes will provide protection for two people.
_____ f. Make sure that your people have the correct information
_____ g. A fire command provides specific information.

## 6-4. Transporting Injured Personnel

Many factors need to be considered when moving or transporting an injured person. Whenever possible, this task is best performed by qualified medical personnel. If it is not possible to obtain medical personnel or if the situation does not permit the lapse of time required to obtain such help, you may be required to move wounded personnel without their assistance.

**461. Identify statements that relate to moving and transporting of injured personnel.**

Whenever possible, transporting an injured person should be accomplished using a litter. This is safer for the victim and easier on you. There may be circumstances that, because of time, location, or situation, make it impossible to use a litter. In these circumstances you may have to provide manual transportation. Where possible, transfer the victim to a litter as soon as practicable. The situation quite often dictates the manual method that you will use. Try to ascertain the extent of the injury prior to transporting. If the person is conscious, he or she may be able to provide information on the injury and cooperate in the transportation.

**Manual Movement of the Victim.** Whenever possible use two people to transport the victim. This will make it easier on both the victim's and the carriers. The type and extent of the victims injuries will dictate the method used. Two methods are shown in figures 6-3 and 6-4.

When transporting a victim by yourself, the fireman's carry is the easiest method. See figure 6-5.

The arms' carry can be used for short distances and for placing the victim on a litter. The victim should be carried high to reduce carrier fatigue. See figure 6-6.

If the victim is conscious, either the supporting carry or the saddleback carry, as appropriate, could be used. These two carries are shown in figure 6-7. With the support carry, you will be serving as a crutch for the victim; and the distance that this carry will work will depend on how far the victim can walk or hop. With the saddleback carry, the victim must be able to hang onto the rescuer.

There may be situations in which you cannot stand erect to carry the victim. In a battlefield condition, to stand erect would be to draw enemy fire. In the case of a natural disaster, such as a tornado, where buildings have collapsed or blown down, there may not be room to stand erect. In this case you may have to drag the victim to a point where you can use a carry. If possible, position victims on their backs, legs straight, and arms secured in their belts. The simplest drag is to seize the collar of the victim and use it to drag him or her out of the immediate danger area. If time


Figure 6–3. Two-person seat carry.

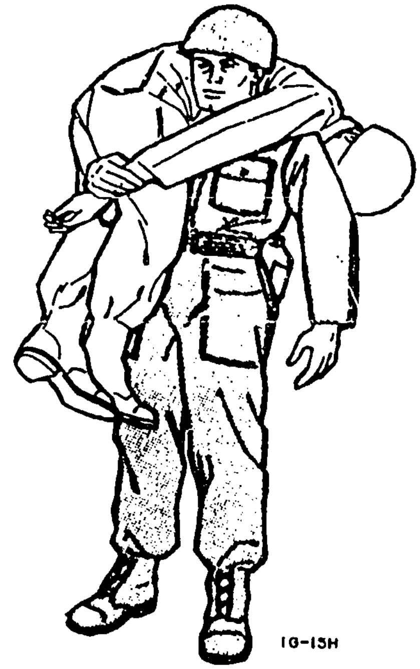



Figure 6–5. Fireman's carry.

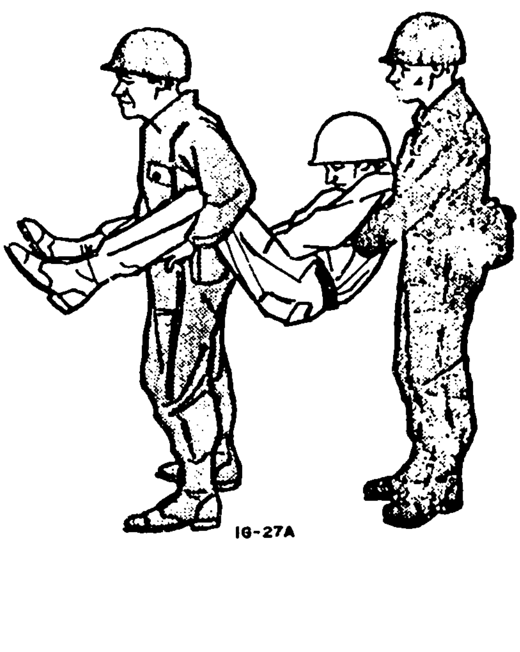



Figure 6–4. Two-person fore-and-aft carry.


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Figure 6–6. Arms' carry.

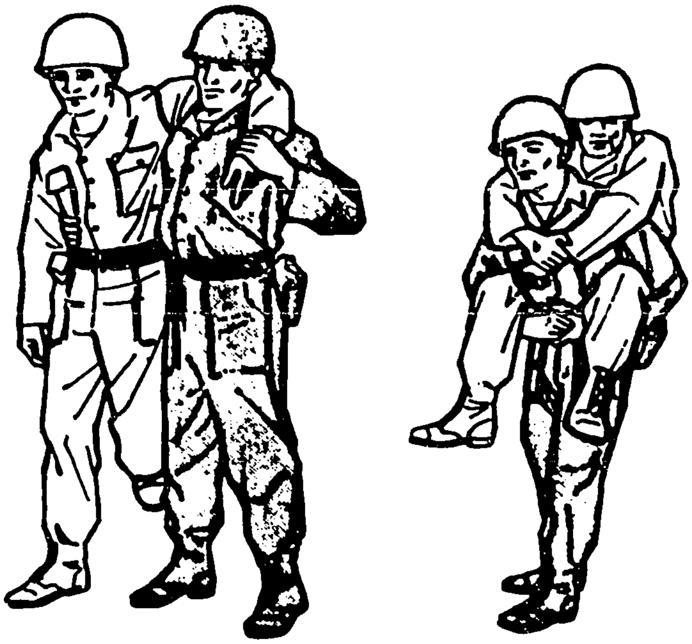


Figure 6–7. Supponing and saddleback carry.

and conditions permit, place the victims on their backs with their arms at their sides. Place your hands under their armpits and seize their outer garments in your hands. You can now back out of the area, dragging the victim to a place where other means of transporting can be used. See figure 6-8.

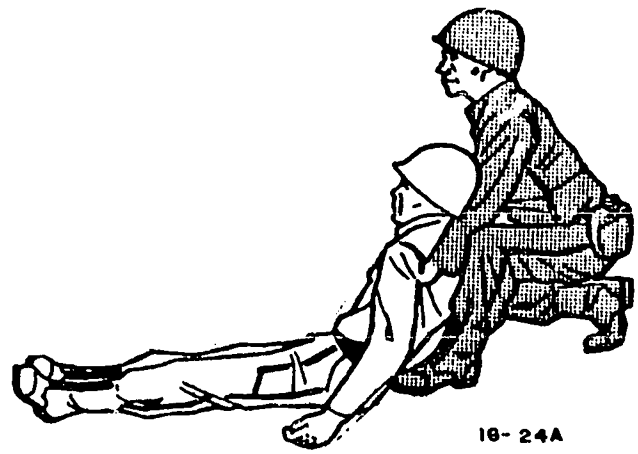


Figure 6–8. Cradle-drop drag.

**Exercises (461):**

Indicate in the space provided whether each of the following statements is true or false.

_____ 1. In all injury cases, speed is the prime concern.
_____ 2. When possible, a litter should be used to transport injured personne!.
_____ 3. When you can, use two people :o transport a victim.
_____ 4. The fireman's carry is the eas:-.st method to carry a victim by yourself.
_____ 5. Never drag a victim.

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# Contingency Training

THE ABILITY to go anywhere on earth and establish and maintain an operational air base has for some time been one of the major Air Force goals. While a great amount of experience has been accumulated in this area over the past years, it is becoming more and more apparent that, in the light of world conditions, even more progress must be made toward this goal. To accomplish this state of readiness, more versatility and ingenuity are being required of each Air Force member. It is no longer enough that you be able to maintain an established wiring system in a well defined base facility. Now you must be able to handle this job under the most adverse conditions. Not only must you be able to perform your normal tasks but you may be called on to help out in other career fields in emergencies. Even the number of different types of situations that you may encounter will be difficult to say. Basically we will limit these to a few general modes. In each of these basic situations we will discuss expedient field methods that you may be required to employ to get the job done.

## 7-1. Expedient Field Methods

The methods that you will use to do your job in a contingency situation will depend on the particular situation. While air transportable electrical kits and collapsible shelters have been developed for specific types of contingency situations, personal experience has been that you are quite likely to end up with fur parkas on Guam and suntan lotion in Alaska. Where the situation is not intended to be permanent or of long duration, or where some local housing is available, you may not have the kits and will have to rely on the local market for your materials. Since a large percentage of the rest of the world is somewhat behind us in wiring requirements, you may not be able to procure materials that you would normally use and will therefore have to use what you can get. What you can get will be determined by local wiring methods.

**462. Specify acceptable expedient methods for constructing service entrances.**

**Expedient Service Entrances.** It may become necessary to build service entrances with expedient methods and materials in the aftermath of either natural or manmade disasters. These installations would be intended as temporary measures only and would be upgraded as the situation stabilizes or used where the base is intended only as a one-time, short-term situation.

If service entrance cable is available, a weather head can be formed with plastic electrician's tape that will effectively seal moisture out of the cable installation for service entrance. See figure 7-1. Individually insulated wires can be bundled, tied with marline, and wrapped with tape to form a service entrance cable. Should plastic tape not be available, friction tape can be used to wrap the cable; however, if friction tape is used, it should be coated with varnish to render it waterproof before it is installed. Care must be used when stapling this entrance cable, to preclude breaking the varnish seal.

Normally, splitbolt connectors or compression splices will be used to connect the service entrance conductors to the service drop conductors. In an emergency, where both conductors are solid, terminal loops can be turned in the conductors and a bolt with two washers can be used to make the connection. This connection should be taped on all hot (unidentified) conductors, but is not required for the neutral (identified) conductor. See figure 7-2

If circuit breaker panels or mains are not available, light loads can be protected by using safety switches for service equipment. It may be necessary to bridge one set of contacts inside the switch so that the neutral will be a solid, unbroken circuit. The hot (unidentified) circuits can then be fused to the proper ampacity through the operating contacts. See figure 7-3. Remember that this is an emergency situation and that the fuses should be well below the ampacity of the branch circuits installed to protect the insulation of these branch circuits. Under any circumstances, some method must be provided to open all the circuits within the structure with a maximum of five hand motions.

**Exercises (462):**

Identify acceptable methods for installing service entrances by placing an X by the acceptable method.

1. Which of the following conductors may be substituted in a service entrance?

   ______ a. Service-entrance cable.
   ______ b. Bare #4 aluminum
   ______ c. Bare #12 copper.
   ______ d. #4 TW if taped and varnished.

2. Which of the following can be substituted for service equipment?

   ______ a. Circuit breaker panels.
   ______ b. Handy boxes.
   ______ c. Safety switches.
   ______ d. Junction boxes.

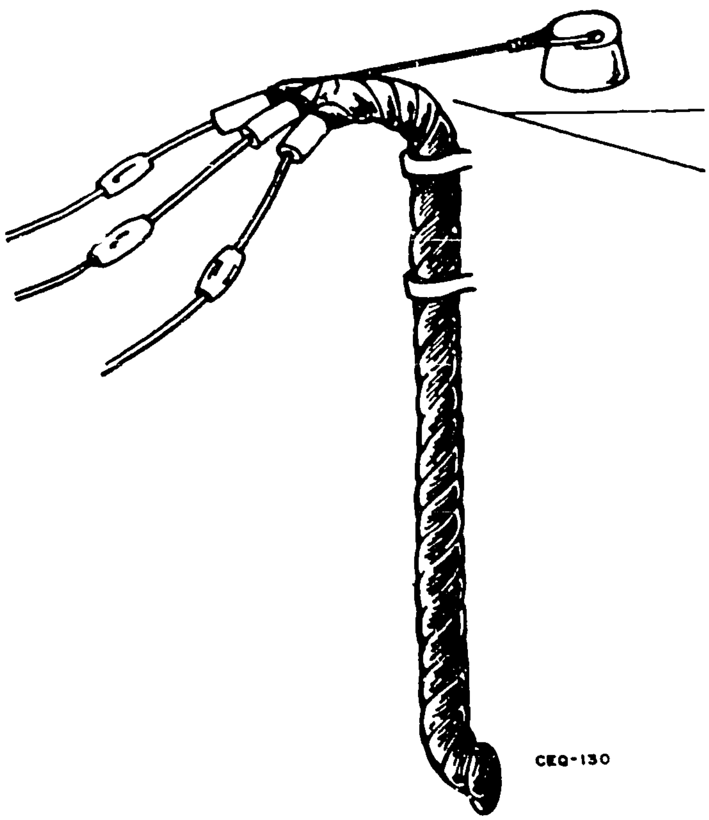


Figure 7–1. Taped weather head.

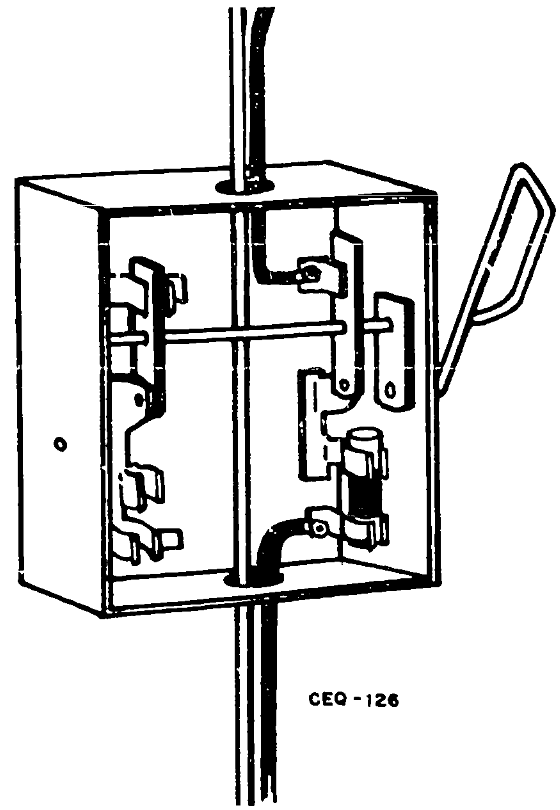


Figure 7–3. Safety switch as service equipment.

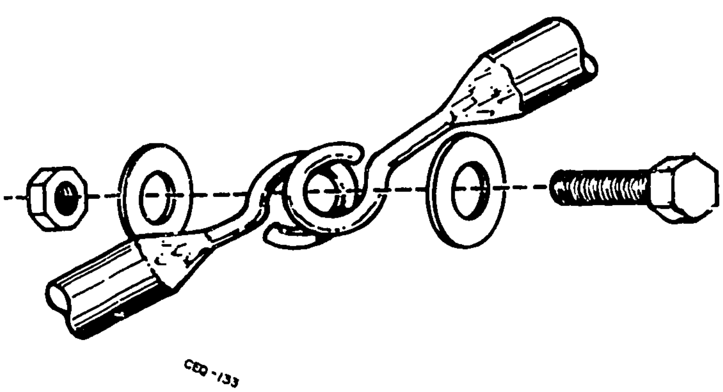

Figure 7–2. Emergency connection.

**463. Describe alternate branch circuit methods that may be used in contingency situations.**

**Expedient Branch Circuits.** One method of wiring branch circuits in a contingency situation is an old method that was used for years and was highly acceptable as a method prior to the development of newer materials. This system is called knob and tube. Basically a knob and tube system is a positive (unidentified) conductor bus and a negative (identified) conductor bus run in an overhead space, such as an attic, with the conductors supported on porcelain split insulators that are fixed to the ceiling joists with nails. See figure 7-4.

Circuits are established as required by tapping into the positive bus wire carried on insulators to the fixture, then from the fixture to the switch and, finally, back and tapped into the negative bus wire. See figure 7-5. Where the conductors pass through floors, ceilings, walls, or other solid wood structures, the wire is insulated by installing porcelain tubes. See figure 7-6.

Originally all taps had to be covered first with rubber tape and then with friction tape. The wire was insulated with an asphalt mixture covered with a cotton braid. The bus wires are normally quite a bit larger than the wires used to supply the separate devices.

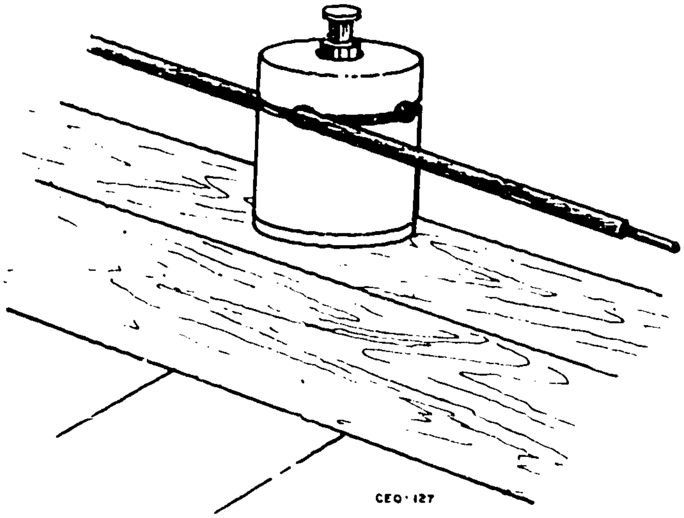


Figure 7–4. Porcelain splitinsulator.

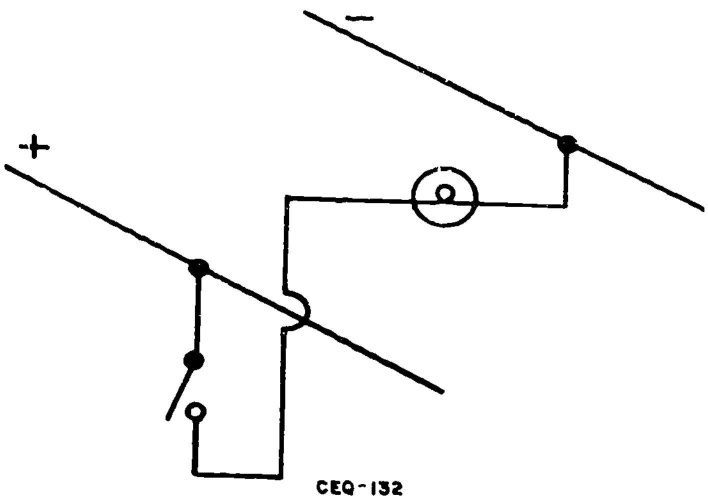


Figure 7–5. Knob and tube circuit.

As you can see, a well installed knob and tube system is an extremely well ventilated and reliable system. They are, however, quite costly in time to build. Poorly made taps will cause arcing and loss of power. Overloading of the system will cause the wire to sag and overheat and can very easily cause fires if the overload continues.

Quite often an adaption of this system incorporated the use of a twisted pair of stranded copper-coated conductors, insulated with rubber, and then covered with a glazed cotton, with green and yellow braid. The pair would be separated for the distance required to make the bus taps. At the point of separation, a ceramic cleat, such as shown in figure 7-7, would be used to secure the twisted pair to the structure. The proper length of cord would be measured off, cut, and a drop socket attached by use of an underwriters knot and screw terminals. Since the drop socket normally incorporated a switch of either the key type (turn) or the chain pull (lavaliere), control of the lamp was at the fixture. Since few-to-no duplex outlets were run with this system, it quickly led to Y sockets and Y sockets in Y sockets so that the circuit was overloaded to the danger p. .nt very quickly.

Either of these wiring methods is efficient and quite safe if properly installed and not overloaded. A large part of the world still uses these systems today because they can be installed for less material cost than any other system.

The very latest factory wiring systems (bus and clip) make use of the principle of efficiently placing equipment or tools where needed and reduce the number of wall and floor circuits. In areas that are controlled, even bare wire of sufficient size and supported by house knobs can be used for a bus system. See figure 7-8. You must remember to supply ample insulation through floors or other flammable parts of the structure and any place where the wires would be accessible to untrained personnel. Sometimes, in a case where this distance would be short, the bare wire could be insulated with plastic electrician's tape. It must be stressed that these wiring systems are for short-term, stop-gap emergency or contingency use only. They are not meant to supply all the electrical power that everybody wants in a normal situation. When a temporary, emergency situation stabilizes into a normal, routine condition, these wiring methods must be replaced as soon as possible!

Another system that can be successfully used under certain soil and weather conditions is a ground return,

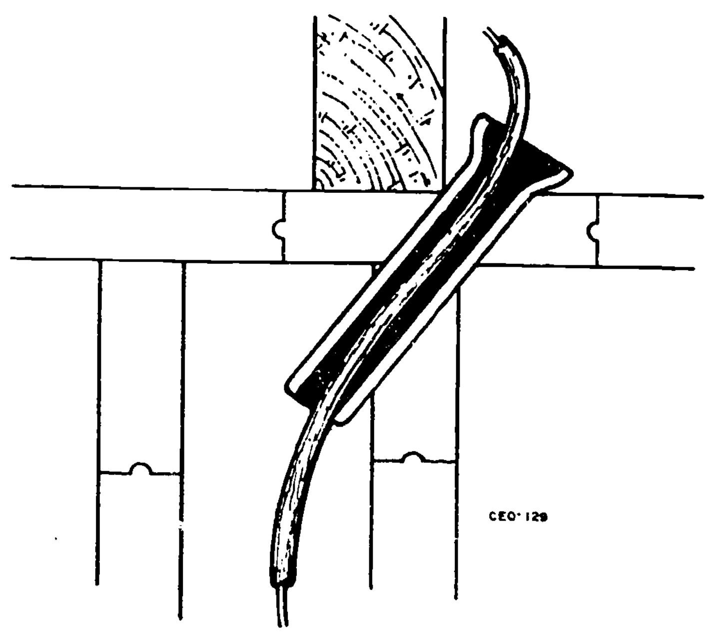


Figure 7–6. Porcelain tube.

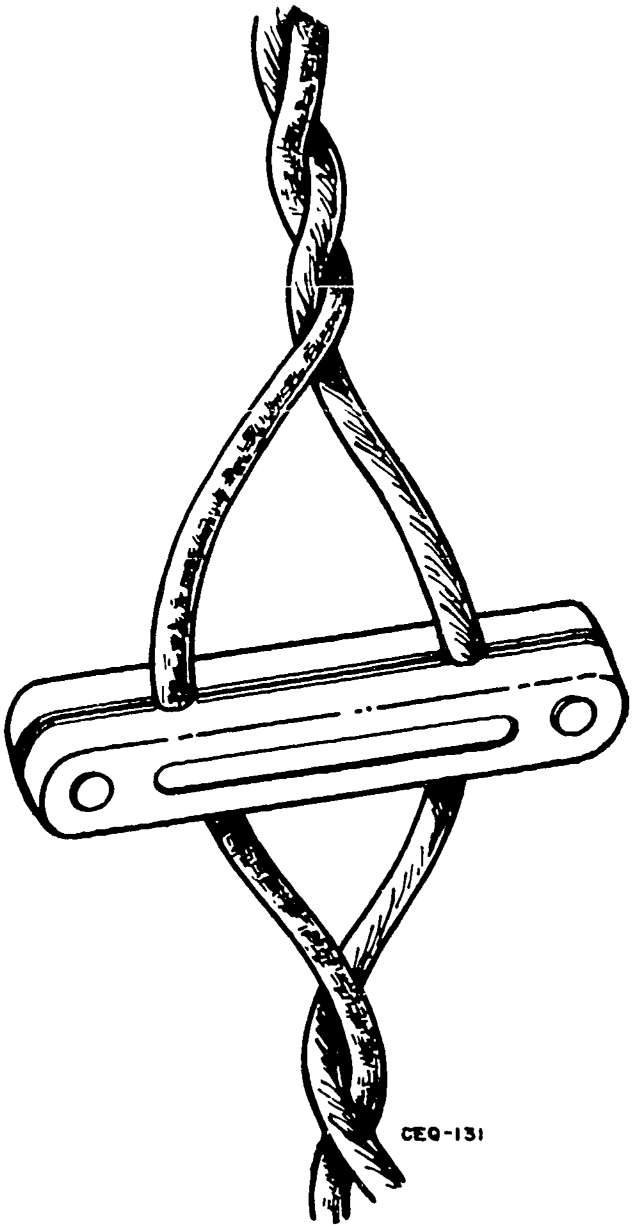


Figure 7–7. Ceramic cleat.

single-wire system. This system is much the same as the electrical system in your car or an aircraft. In this case the earth is used as the neutral wire. It is very easy to see the danger inherent in this system under certain circumstances. It should not be used where the ground is either very dry or frozen, since in either case the ground return could be lost to an individual unit. Also with this system, no case ground is provided for your protection. Normally this system will be used only where the generating equipment is in close proximity to the using equipment.

In some exceptionally cold areas, it may not be possible to get a driven earth ground because the top of the ground is frozen to a depth that will not permit a ground return. In this case, it may be necessary to run a network of bare copper wire on top of the ground between all the using points, from the using points to the generating point, and from there to some earth ground. It may be necessary to bore wells through the frozen surface and lower anodes into the wells to a depth where earth heat and ground water will make a ground.

In exceptionally dry or sandy areas, additional ground rods may be required to get the proper ground resistance.

**Exercises (463):**

1. List three alternate methods of constructing a branch circuit and describe the requirements and materials used for each one.

2. For each of the situations listed below state which branch circuit method is being used.
   a. A drop socket is attached where the wires of a circuit have been separated.

   b. Wires leading to a duplex outlet are tapped off a positive and a negative bus wire.

   c. A single wire is run throughout the circuit with each unit connected to this wire and ground.

**464. State expedient procedures to be used when interfacing with foreign wiring systems.**

Another type of contingency situation is reactivating an established base in a friendly foreign country. In this case, the basic facilities of the base would be intact but possibly requiring renovation or modification.

**Comparison of Foreign and U.S. Wiring.** The primary difference between U.S. and foreign wiring systems is that most foreign systems have not been installed according to the standards outlined by the U.S. NEC. This fact may be attributed largely to the material shortages in most foreign countries, which have dictated the use of materials at hand. In many instances, these would be considered below standard in the U.S.

*Voltage*. The U.S. uses nominal voltages which range from 120 to 240 volts for single-phase AC and 208 to 600 volts for three-phase AC for low-voltage distribution. Though these are considered to be standard voltage ratings because of their prevalent use, some locations and areas in the country use AC systems with nonstandard voltages.

A considerable number of foreign countries use voltages other than those we accept as standard. Consequently, during occupation or wartime, our electrical equipment has

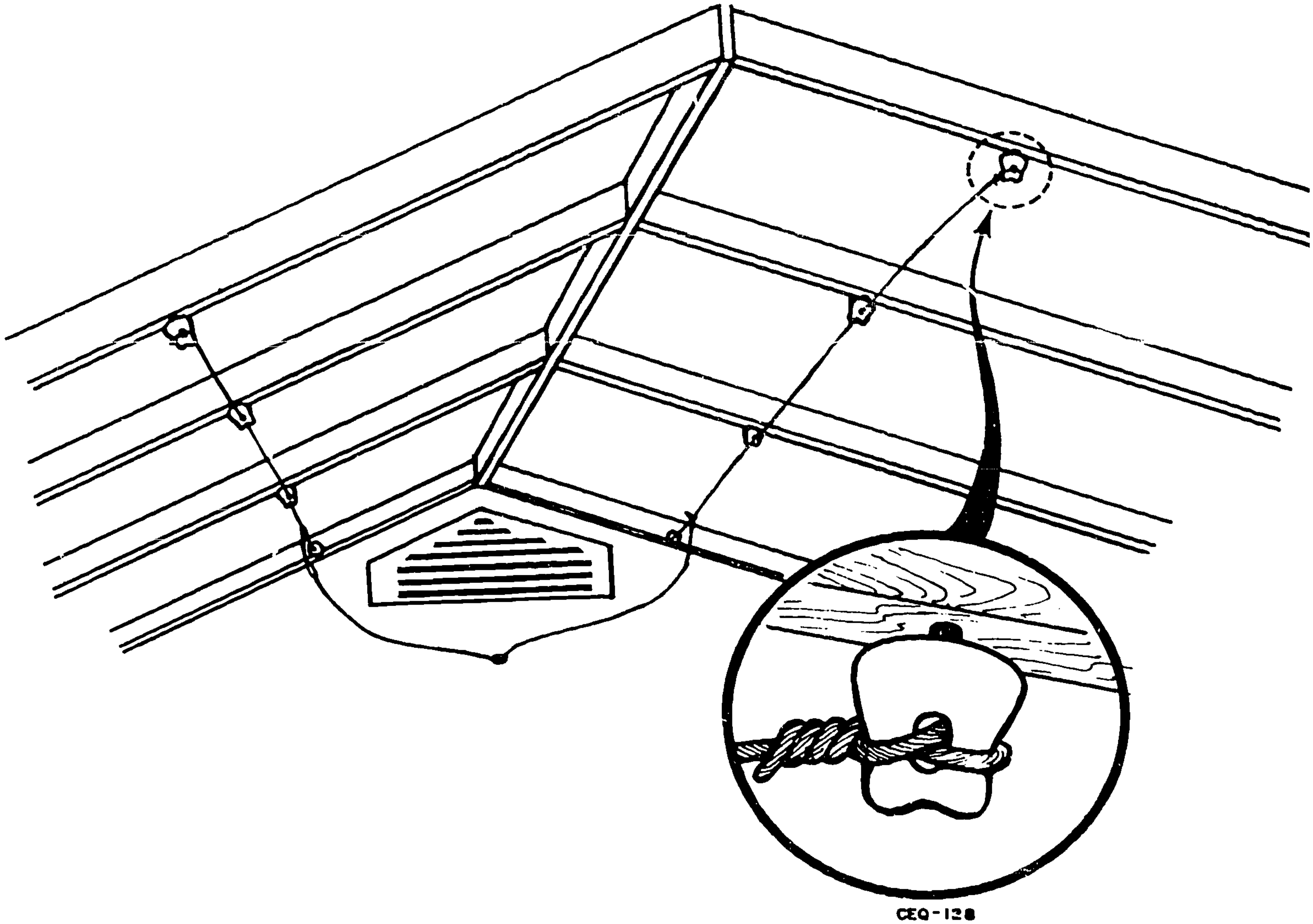


Figure 7–8. House knob.

to be converted, modified, or operated inefficiently when powered by foreign electrical installations.

*Frequency,* The standard frequency of AC distribution in the U.S. is 60 cycles. In most foreign lands, 50-cycle frequency generation is common; but the electrician may also encounter such frequencies as 25, 40, 42, and 100 cycles.

*Materials.* The wiring materials commonly used in foreign countries are usually peculiar to the territory's manufacture. In recent years, the large export of electrical goods from Germany, England, and the United States has been increasingly reflected in the established wiring patterns.

The U.S. employs the American Wire Gage system, denoted by the symbol AWG, which is peculiar to our installations. However, the majority of the foreign wire which you may use will differ in size and use.

The receptacles, switches, and plugs used in foreign wiring systems are also peculiar to the installations found in a particular area and normally cannot be mated or used with similar types of receptacles manufactured in the U.S.

**Expedient Procedures.** During a contingency operation in a foreign territory, the Air Force may use all or part of a foreign electrical installation. Though the decision of employment is largely determined by the immediate circumstances, the Air Force electrician or unit commander will follow one of two general procedures:

*a.* Since the electrical components of a foreign and domestic electrical system cannot be interchanged, the decision may be made to use all foreign equipment. The problem in this case is one of supply. The parts needed may not be available.

*b.* If time is a factor, consideration should be given to the use of standard electrical items made in the U.S. and the modification of plugs or connections so that they may be used with the foreign system. Though this method usually results in decreased operating efficiency, the ease of

adaptability and abundance of supply usually outweigh the reduction in performance.

*Effects of voltage differences*. All equipment should be operated at its rated voltage. To expedite foreign system use, the items built to operate at standard American voltages may have to operate at different voltages. Though they may not be operated efficiently, their availability for use may be an important military advantage. Some effects of voltage differences on common electrical devices are listed below.

*a*. When fluorescent lamps are operated at voltages higher than standard, both the lamp and ballast life are shortened. Line voltages below the minimum of the operating ranges of 110–125, 199–216, or 220–250 volts will cause uncertain starting, short lamp life, and reduced lighting efficiency.

*b*. When incandescent lamps are used and operated at voltages higher than their normal ratings of 114, 120, and 125 volts, they also have a shortened lamp life below that expected; but their light output is increased. Conversely, if the line voltage of operation is below standard, the life of the lamps is increased; but the lighting efficiency is reduced approximately 3 percent for each 1 percent drop in rated voltage.

*c*. Rotating equipment, such as motors and fans, is usually manufactured to operate with a permissible voltage variation of 10 percent within their prescribed rating. The combined voltage and frequency variation is also limited to 10 percent. Higher voltages give increased torque, increased efficiency, and increased starting temperature. A lower operating voltage results in decreased torque, decreased efficiency, and increased running temperature. Operation at voltages differing from rated voltage by more than 10 percent may be permitted only in an extreme emergency, since the equipment may be damaged or destroyed by such operation.

*Effects of frequency differences*. Electrical operating items based on resistance characteristics (such as heaters, hotplates, electric stoves, and so on) operate efficiently over all ranges of distribution frequencies used throughout the U.S. and foreign territories. Rotating equipment and items such as lights and transmission or receiving equipment are adversely affected by variations in frequency. Some of the effects of frequency changes on this type of equipment are:

*a*. Fluorescent lights rated to operate at a nominal 60-cycle current can be used at 50 cycles, but with a shorter ballast life. At lower than 60-cycle frequencies, a noticeable flicker in the light output can be seen. This is undesirable where painstaking and meticulous work is being performed. Operation at lower frequency is not satisfactory and should be avoided.

*b*. Incandescent lights, because of their resistance design, will operate satisfactorily at all of the frequencies encountered overseas.

*c*. Motors should not be connected to power distribution systems whose frequencies vary more than 5 percent from their rated limits of operation. Some motors are built to function at either 50 or 60 cycles. Their shaft speed is directly proportional to the frequency of the power supply. Consequently, if a motor is nominally rated to run at 1800 rpm at 60 cycles and is operated at 50 cycles, its output speed will be 1500 rpm. Special motors with considerably larger frames must be obtained for the same power outputs at lower frequencies.

*d*. All receiving and transmitting equipment or other items which have transformers included in their wiring will not operate satisfactorily either below or above their rated line frequency and should be used only in an emergency. In some cases, there may be frequency changers that can be obtained and used when the equipment is essential to the mission.

*Effect of material differences*. When dissimilar materials are used interchangeably in a power-distribution system, problems may be created. The close association of dissimilar metals may cause galvanic corrosion at the joints which eventually destroys the usefulness of the equipment. This is of particular concern when aluminum and copper are joined. New materials are specially made for connection to copper or aluminum with no adverse effects. This equipment will be so marked. Except in emergencies as an expedient installation, dissimilar metals must never be used together. If aluminum is exclusively used in a system, a special joint compound must also be applied to all connections or joints to protect the connection against excess surface oxidation. This is necessary because the oxide of an aluminum conductor differs from copper oxide in that it adds a high contact resistance to the wire.

**Exercises (464):**

1. State the primary difference between foreign wiring systems and U.S. wiring systems. To what is the difference attributed?

2. During an occupation or wartime, electrical equipment used on foreign voltages other than those we consider standard must be ____________, ____________, or operated ____________.

3. What two expedient procedures are open to the electrician or unit commander when all or part of a foreign installation is used during a contingency operation?

4. Describe the effects of low voltage on fluorescent lamps and ballasts.

5. When receiving and transmitting equipment is used that is essential to the mission and the frequency available is different from that required, what procedures should you take?

6. Aluminum conductors and connections used exclusively in a wiring system require what specific action to prevent excessive surface oxidation?

## 7-2. Military Vehicle Operations

In addition to your data identification number (DIN) truck and maintenance trucks, you should be familiar enough to safely operate other military vehicles should the necessity arise. The following information is basic to most military vehicles.

**465. Identify procedures basic to vehicle operation during contingency situations.**

**Operational Checks.** Perform a walkaround inspection of the vehicle and check for obvious damage. This will include dents, broken lamps or glass, or parts missing. Check tires for cuts, wear, direction of rotation, and proper inflation. Use a pressure gauge to check tire inflation. Check under the vehicle for evidence of leaks of oil, fuel, hydraulic fluid, water, antifreeze, or brake fluid. Look for loose nuts or bolts. See if the windshield wiper blades are adequate.

Check fluid levels and electrical connections, as well as belts and pulleys. On some vehicles it will be necessary to drain the airbrake reservoir to remove condensation. All discrepancies should be noted on the appropriate forms.

When you get into the cab, familiarize yourself with the location of the controls and gauges. Adjust the seat and mirrors and fasten the seatbelt.

The starting procedures will vary with the vehicle; however, basic procedures will be much the same. Place the transmission in neutral with the clutch disengaged, set the auxiliary parking brake "on" and turn the ignition switch to "start." If the engine does not start within 30 seconds, turn the switch off and allow the starter to cool. In other military vehicles, the starter switch is engaged by the left foot after the clutch is depressed with the same foot.

As soon as the engine starts, scan the gauges or indicator lights. Check the oil pressure gauge or indicator light first. If no oil pressure shows on the gauge or the indicator light remains lit with the engine running, shut the engine down. If the oil pressure is satisfactory, check the oil and water temperature, ammeter or generator light, and if applicable, airbrake pressure. After checking all engine operation indicators, you should slowly release the clutch with the transmission lever in the neutral position to allow the transmission fluid to circulate in the transmission.

Check the lights, horn, wipers, and any other additional equipment. Before driving the vehicle, test all brakes for operation, check mirrors, scan the area surrounding the vehicle, and release the parking brake. Depress the clutch, engage the transmission lever, and drive off. During operation, keep a check on the engine operation instruments and remain alert for visual, audio, or "feel" indications of developing trouble. To help prevent troubles from developing while using the vehicle, observe the load limits for the vehicle. Do not attempt to drive it in places it is not designed to go. Treat it as if you were going to buy it because if you don't—you may.

**Post Operational Checks.** Before taking the vehicle out of operation at the end of the day, make sure that the fuel tank is at least 3/4 full. This will help reduce condensation and assure a sufficient fuel in case of an emergency. If you must leave the vehicle, shut off the engine, put the transmission in park or reverse, set the auxiliary brake and, if parking on a grade, block the wheels. Before you turn in the vehicle, clean it, note any discrepancies that showed up during operation on the proper form, and drain the airbrake tank reservoir to remove condensation and air. Close the cock after draining. If the vehicle requires maintenance, turn it in for repairs.

These are general guidelines for all military vehicles. It should be remembered that each vehicle will have its own special requirements that should not be overlooked. An example of this would be the forklift. Most forklifts are basically operated by hydraulics. Be sure to check the reservoir, lines, and cylinders. Be sure to use the correct parts and fluids during repair. Care must be used when mounting or dismounting this equipment. Use the steps and handrails provided. When the forklift is parked, make sure that the forks are lying flat on the ground.

This text cannot cover each and every vehicle type that may be used in all contingency operations. The items covered herein are basic to most vehicles whether they are U.S. Government property or foreign built. If you don't know, ask someone who does. Don't take a chance on tearing up the equipment or killing someone. These vehicles will most likely be the only ones that you will have, so it is in your best interest to assure that each vehicle performs as well as it can during the emergency.

**Exercises (465):**

1. What should the preoperational inspection begin with?

2. What may you spot by looking under the vehicle?

3. What should tires be checked for during the preoperational inspection?

4. From the time you enter the cab until you engage the starter, what steps should you follow?

5. Which engine operation indicator should you check FIRST after engine crank?

6. Why should you slowly release the clutch with the transmission lever in the neutral position?

7. Why should the air tank be drained after operation?

8. What is the minimum amount of fuel that must be in the tank before the vehicle is parked at night and what is the logic behind this requirement?

9. What transmission lever positions are acceptable when parking the vehicle?

10. Most of the basic operational functions of a forklift are performed by ____________.

11. Before a forklift is left for the day, what should be the position of the forks?

**466. Specify field recovery procedures and the proper use of field expedients, including vehicle camouflage and concealment, in convoy movements.**

**Field Recovery.** A knowledge of certain field recovery operations will help you to keep your vehicle mobile during field operations.

*Changing tires without a jack.* On single axle, single wheeled vehicles, drive the wheel with the flat tire onto a large rock or block to raise the wheel. Secure the vehicle by setting the handbrake and blocking the rest of the wheels. Block up under the axle next to the flat. Dig the soil from under the block or rock that the wheel is resting on to allow the axle to settle onto its blocking. Remove the block or rock from under the tire and install the spare.

After the spare is installed, you must get the vehicle off the blocking. If it is a front wheel, merely drive off the blocking. On a rear wheel, you will have to provide traction some way. Vehicles with front-wheel drive can be driven off by engaging the front wheel drive. Those with standard two-wheel drive will require some work. Attempt to push the vehicle off the blocking. If this fails, fill in under the tire to raise the vehicle and to provide traction to the wheel. Vehicles equipped with differential lockouts can be driven off by locking the differential.

Flats on inside duals can be changed by using essentially the same procedure. However, use a 2-inch block under the inflated tire to raise the vehicle. Block the axle and proceed by digging the soil out from under the block. Complete the job by following the above procedures.

The procedure for changing an outer dual is very simple. Drive the inside tire onto a block and change the outer wheel. In fact, this system is easier than using a jack when one is available.

A vehicle can also be raised to change a tire with a strong pole and block. Place the block near the hub or axle and insert one end of the pole under the hub or axle and over the block. Weight is then applied to the lever end of the pole to raise the vehicle. Place another block under the raised end of the axle. Be sure to exercise extreme caution, since the pole may slip, causing the vehicle to fall.

*A-frame use.* Another means for lifting the front end of a vehicle is with an A-frame made with two strong poles and a tow chain. Figure 7-9 shows how an A-frame is devised and shows its positioning in relation to the front of the vehicle. After the A-frame is prepared, back the vehicle until the A-frame is in an upright position.

The height to which the vehicle is lifted off the ground with an A-frame is controlled by the amount of slack left in the chain. The greater the slack, the less distance the vehicle will be raised.

*Towing.* Prior to towing any vehicle, refer to the vehicle manual for specific instructions. However, the following are some general rules for towing:

*a.* Move towed loads at reduced speeds and avoid quick starts and stops.

*b.* Mark towed vehicles with warning lights or flags.

*c.* Use a wrecker whenever possible; it is designed for towing.

*d.* Use a towbar in preference to chains, ropes, or cables. If cables, chains, or ropes are used, connect them to the pintle hook of the towing vehicle and to the lifting shackles or tow hooks of the towed vehicle. On vehicles without lifting shackles or tow hooks, attach the towing device to the front end of the frame. A driver is necessary to control the towed vehicle when using a chain, rope, cable, or some types of towbars.

*e.* If you must tow in heavy traffic without a towbar, tie the front bumper of the towed vehicle tightly to the rear of the towing vehicle. If both vehicles have airbrakes, connect the airhoses between the two vehicles. The electrical cable for brake and signal lights must also be hooked up to the towed vehicle. A driver is not necessary to control the towed vehicle for this type of hookup.

*Obtaining traction.* Traction may be obtained by placing material in front of and as far under a vehicle's wheels as

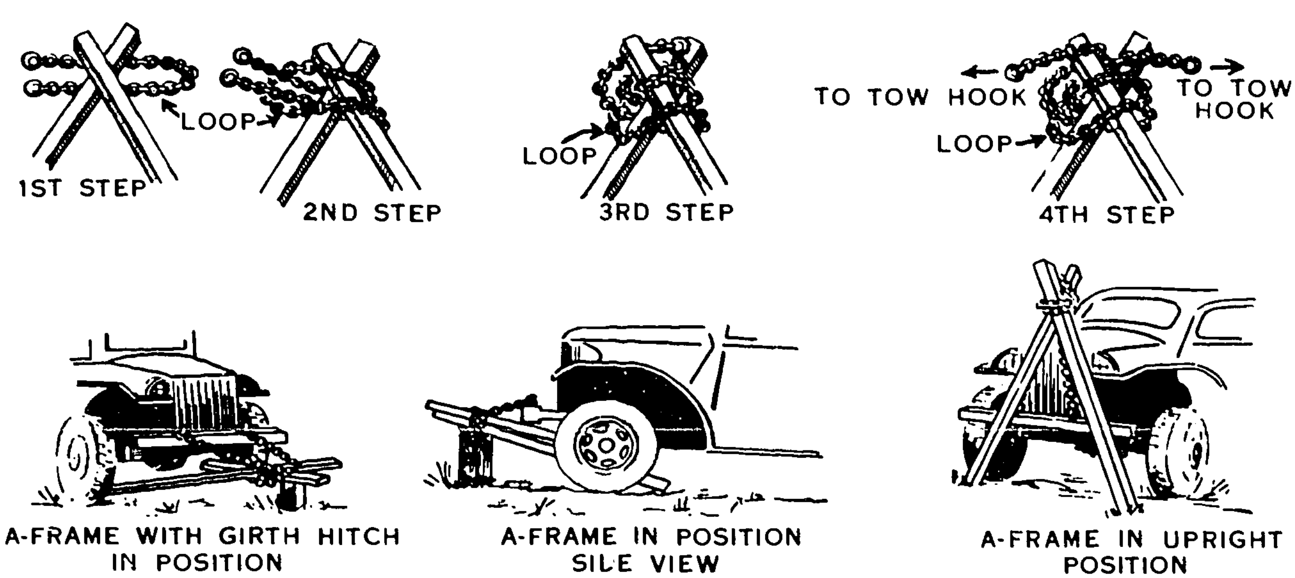

Figure 7–9. A-frame lift.

possible. Do not block forward movement of the wheels. Drive wheels may be jacked up and traction and flotation increased by placing material directly under the wheels. If you don't have a jack, a pole can be used as a lever under the hub or axle to raise the wheels.

Rope or tow chains can be wrapped around the wheels as tire chain or track substitutes. Be sure to fasten them securely, but leave slack around the tires to prevent tire injury. These are only temporary substitutes and must be removed as soon as possible.

When one of the power wheels of a vehicle is lodged in a deep hole, try digging the soil from in front of the wheel with a shovel, mattocks, pick, or an axe. If this is unsuccessful or the soil is extremely hard and towing equipment or a winch is not available, obtain a heavy timber or log long enough to reach across the hole in front of the wheel (fig. 7-10). When power is applied tc the wheel, the wheel will rise. Be careful, however, to prevent breakage of parts when applying power. As the wheel rises, have someone to fill the hole with rocks of other suitable material to prevent the wheel from falling back into the hole.

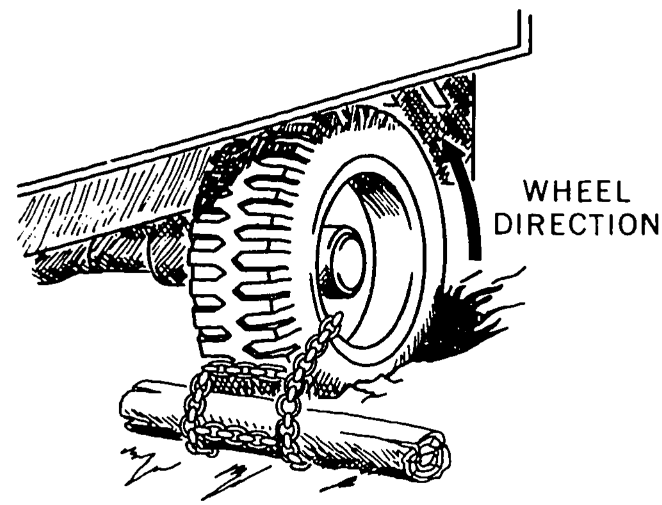

Figure 7–10. Timber chained to drive wheels.

*Damaged or inoperative rear wheels (vehicles with two or more driving axles).* With a means to jack up the vehicle, some chain, and a piece of timber, rig the vehicle so that it can be driven to a repair point. However, the following procedures must not be used on heavily loaded vehicles or on those traveling long distances.

To rig a small, four-wheel drive vehicle with a damaged or inoperative rear wheel, use a skid or timber as shown in figure 7-11. Lash a skid of timber to the frame or chassis so that it extends under and beyond the rear axle. The skid should be long enough so that the lower end does not dig too deeply into the ground. The strength of skid, nature of damage, and type of roadway will have to be evaluated and a decision made as to the necessity of removing the wheel.

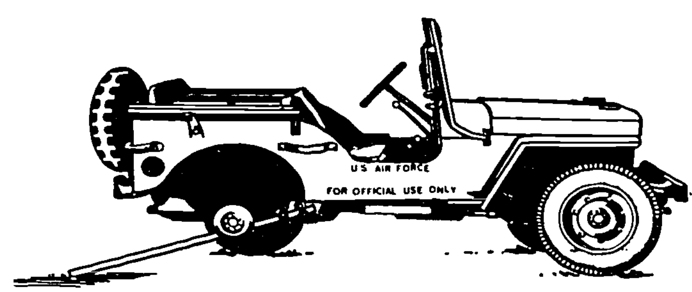

Figure 7–11. Skid lashed to frame.

After the skid is secure, proceed in front wheel drive. If the wheel is locked, remove the axle shaft on that side or disconnect and remove the rear propeller shaft to allow the other wheel to rotate freely.

To rig the rear axle of a six-wheel drive vehicle, chain the damaged axle to the rear corner brace as shown in figure 7-12. When the repair involves the intermediate axle, all procedures are the same except that tieup is made to the crossmember directly above the axle. Be careful in tying up either axle to prevent damage to the brake lines. In case of a locked wheel, remove the axle shaft or the proper propeller shaft to permit the opposite wheel to turn freely; then proceed in normal drive.

*Winch operation*. The winch is one of the most valuable pieces of equipment for field recovery of vehicles. Since the actual operation of a winch varies according to the type, use the vehicle manual for the details of winch operation. However, the general uses of a winch are discussed here:

*a*. Pulling your vehicle. Pull the vehicle with its winch by anchoring the cable to an object, such as a tree or pole, that will withstand the pull. Engage the winch; as the cable is wound on the drum, the vehicle is pulled toward the anchor. This method of winching is a single line straight pull, as shown in the top illustration of figure 7-13. It is the least desirable method, because all of the load and strain is concentrated on a single line.

A snatch block, as shown in the center part of the figure, divides the strain on the cable between two lines and will smooth out the jerks. A snatch block is a device with a sheave (pulley) around which the cable or rope is run.

However, the best method of winching is shown in the bottom part of the figure. This method uses both the spreader bar and the snatch block. This procedure divides the strain between the two front lifting shackles and provides a straight pull on both the cable and winch.

*b*. Pulling an object. To pull another object with a vehicle's winch, the vehicle must be held in place while the object is being moved. This may be done by applying the brakes or placing wheel blocks in front of the tires. Some vehicles are equipped with an electric brake lock which is used to hold the service brakes during winching operations. If necessary, anchor the vehicle from the rear by running a cable from the vehicle's pintle hook to an anchor. This cable should be run to give the longest reach and the straightest pull possible.

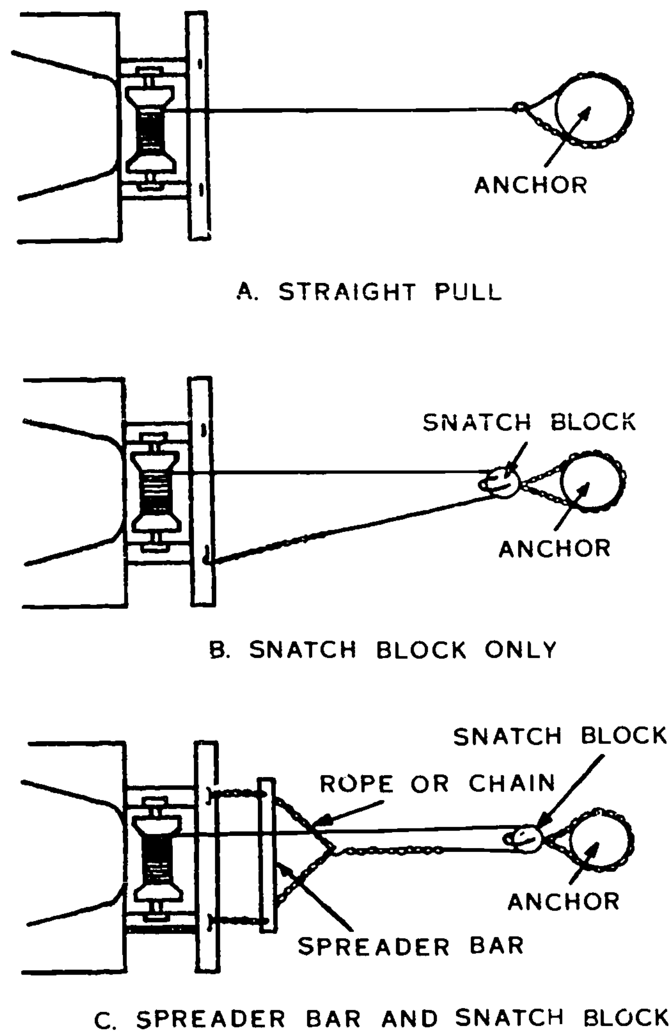


Figure 7–13. Winch operation.

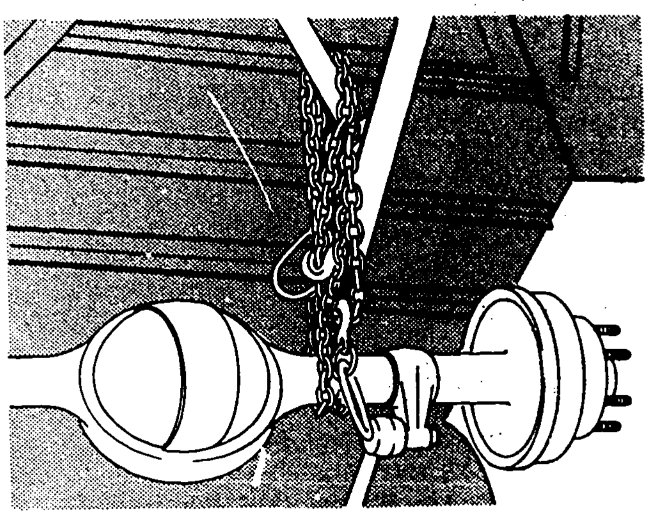

Figure 7–12. Damaged axle chained to brace.

After the vehicle is secured, objects may be pulled by the winching methods shown in figure 7-13; the anchors in the illustration would represent the object being pulled.

*Winching safety*. The following are some winching safety precautions. Careful observance of these precautions will help prevent injury to personnel or damage to equipment:

*a*. Winches are equipped with an automatic safety brake to hold the winch load when the winch controls are being shifted. The brake adjusting screw should be kept loose until the brake is required to hold a load. If the screw is tight during other uses of the winch, the shear pin will break or the brake lining will be needlessly worn.

*b*. Do not permit vehicles with metal tracks to run over the cable. Such abuse flattens the cable, exposes the hemp core, and permits water to enter, causing internal rust and weakening of the cable.

*c*. Have personnel stand clear of a winch cable before it is tightened. A cable under load may break and whip back with force enough to kill or seriously injure a person.

*d*. After using the winch, pull back on the cable while it is wound slowly and evenly on the drum.

*e*. Keep the cable lubricated.

*f*. A shearpin is provided on winches to protect the cable and other winch parts. When the winch is overloaded, the shearpin breaks. Never use makeshift shearpins of unknown strength to replace a broken pin; too strong a pin may cause the cable to snap. Use only authorized replacement pins. Don't depend on the shearpin for protection. Even with the proper pin installed, a kinked, frayed, damaged, or weakened cable may break.

*Dual wheels as a winch*. If the vehicle is not equipped with a winch, but has dual wheels, employ the dual wheels as a winch. This is done by fastening a rope between the dual wheels on one side of the vehicle and another rope between the corresponding duals on the other side.

Draw the ropes taut; then fasten the free ends to an anchor. When power is applied to the wheels, the ropes will wind up between the dual wheels and exert a pull on the vehicle.

To move another object using the dual wheels as a winch, block up the driving axle and anchor the vehicle. Then fasten one end of the rope to the duals and the other end to the object to be moved. Applying power will wind up the ropes, drawing the object toward the vehicle.

*Anchorages*. When an anchor is needed during winching operations, use a tree stump, large rock, etc., when available. It may be necessary to devise an anchor. Two types of anchors that can be made are the "deadman" and stake anchor.

The deadman is made by sinking an object (log, spare tire, etc.) in a trench in the ground as shown in figure 7-14. Trench depth depends on the firmness of the soil and the size of the object used. Cut the trench at an angle away from the direction of strain to keep the object from sliding upward when a pull is applied. If the ground is extremely hard, and the object cannot be buried deep enough to prevent sliding out, drive at least two stakes in the ground on the pull side of the object. The stakes must bear against the object and be slanted away from the pull. A slot is cut perpendicular to the center of the trench and slanted upward from the bottom at about a 45° angle to form a pathway for the cable.

To devise an anchor with stakes, drive two or more strong stakes from 3 to 4 feet apart into the ground, as shown in figure 7-15. Each stake must be driven at an angle away from the direction of strain, but the stakes must be in line with the direction of pull. The number of stakes needed depends upon the firmness of the soil and the amount of pull to be exerted on the anchor.

After the stakes are driven in the ground, tie a rope to the bottom of the stake farthest from whatever is being anchored. The rope is then run to the top of the next stake in line and secured. Then you run the rope back and forth around the two stakes a few times and secure its end. If more than two stakes are needed, repeat the preceding process with additional stakes and ropes. Tie each new stake to one of the previously tied stakes. Whatever is being anchored is then fastened to the lower portion of the nearest stake.

**Vehicle Camouflage and Concealment.** A stationary vehicle can best be camouflaged by placing it under natural vegetation (trees or large bushes) so that its regular pattern of shadow is broken up. All parts likely to reflect light must be covered.

Where trees or bushes are not available, fish net or chicken wire scattered with artificial material or with natural vegetation can be used to cover the vehicle. When snow is on the ground, cover the vehicle with white cloth or paint the vehicle white. Be sure that the color and texture blend with the surrounding area.

Moving vehicles cannot be successfully camouflaged artificially. Use roads where the vehicle is concealed by natural vegetation. Avoid dusty roads, because there is less chance of the enemy's detecting vehicle movement. Take advantage of natural cover or concealment if operating alone and you are attacked by a' craft.

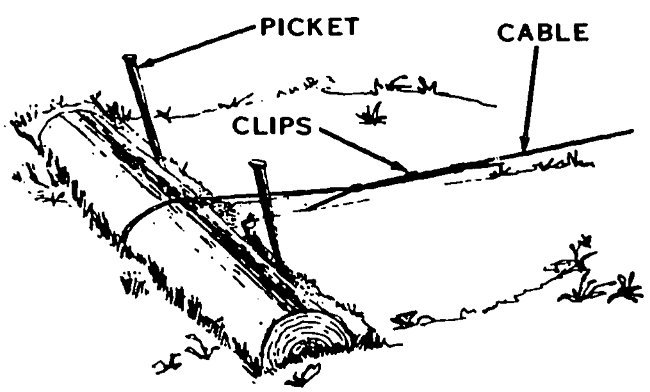


Figure 7–14. Deadman and stake anchor.

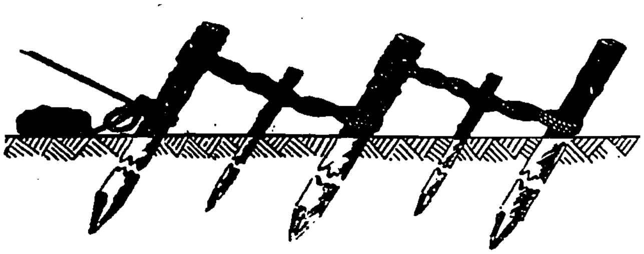

Figure 7–15. Anchor with stakes.

When entering a parking area, use existing paths to prevent changes that would be readily apparent to the enemy. If not possible to otherwise conceal the tracks, continue driving beyond the planned position of the vehicle. Then return to the selected parking spot. Avoid all visible movement when enemy aircraft are in the vicinity.

**Exercises (466):**

1. How would you change a flat tire if the tire goes flat on the inside dual?

2. If traveling across rough terrain and the drive wheel of the vehicle falls into a deep hole, what method should be used to get the vehicle out?

3. How is a properly fastened A-frame used to raise the front end of a vehicle?

4. What is the safest, prefer ... d of towing a vehicle, assuming that a wrec... not available?

5. Complete this statement: To rig a small, four-wheel drive vehicle with a damaged or inoperative rear wheel, use a ____________ of ____________.

6. (1) Which winch operation is the least desirable for field recovery? (2) Which is the most desirable?

7. During winch operations, what happens if the brake adjusting screw is left tight?

8. Explain the procedures for using the dual wheels of a vehicle as a winch.

9. What method can be used to camouflage a moving convoy?

10. Why is it important to use existing paths when entering a parking area under possible enemy observation?

**467. Indicate proper procedures for a vehicle operator to use in making emergency repairs, including jump starts.**

When maintenance help is not available and your vehicle breaks down, you can perform the emergency (chiefly minor) repairs described below.

**Flat Tire.** Replace a flat tire with the spare if one is available. If not and the vehicle has dual wheels, use one of the duals to replace a flat front tire.

**Dragging Brakes.** Make adjustment according to the instructions in the vehicle manual; the method will vary with different vehicles.

**Braken or Leaking Hydraulic Brake Line.** if the break is in a metal brake line to one of the wheels, hammer the broken line flat at any point between the break and where it joins the line to the other wheel. Breaks in the rubber flex lines can be repaired by cutting the hose, doubling the supply end back, and twisting a wire around it tightly. This method is preferable to flattening the metal line since repairs are easier and cheaper. Be careful when braking after the emergency repair since the brakes will pull to one side. If the hydraulic brake fluid has leaked out, add water to the master cylinder as a substitute for brake fluid or depend on the handbrake. Use of the handbrake requires low speed and use of the lower gear ranges. The handbrake functions on the rear wheels only and is not too effective for stopping.

**Broken Airbrake Line.** Pinch or hammer the broken end of the line shut. If a brake cylinder diaphragm is ruptured or leaking badly, clamp or hammer the line flat that leads to the damaged cylinder.

**Punctured Gas Tank.** Repair the leak by cutting a plug of soap or wood and pushing it tightly into the hole. Leaks in gaslines may be retarded temporarily by firmly wrapping string around the leaking line and then covering the string with soap. Plastic film wrapped tightly around a fuel line and tied or taped tightly will also retard fuel leakage.

**Punctured Radiator Core.** Cut a wooden plug and push it tightly into the hole. If there is a large puncture, cut the cooling fins away and push back the good tubes from those that are damaged in order to give room in which to work. Fold ends of the broken tubes back about three quarters of an inch and close the ends by pressing them flat. If feasible, loosen the radiator cap to reduce system pressure.

**Vapor Lock.** A vapor lock is caused by gasoline vaporizing in the fuel supply system. If the vapor lock occurs after a stop of a few minutes, pour cold water over the fuel pump to condense the vapor. In case water is not available, open the hood and let the engine cool. When a vapor lock occurs while the vehicle is in operation, use a wet rag and carefully wrap it around the fuel pump and sediment bowl. You can usually do this without removing the bowl from the fuel pump.

**Broken Fan Belt.** A substitute fan belt can be made from a small rope or from a strand of a larger one. Loosen the generator and apply the rope; tie the ends with a square knot. Then tighten the generator and trim the knot. If sufficient adjustment is available, the ends of the broken belt may be wired together as a temporary repair.

**Cracked or Broken Fuel or Oil Line.** Break the line and install a piece of hose (from the windshield wiper or air horn) over the ends. If this makes the wiper hose too short, plug the opening to the engine with a wood plug. Another temporary repair can be made with a tight wrapping of tape or other nonporous material secured with closely wrapped wire or string.

**Wet Ignition System.** Wet distributor and ignition system components may be dried by wiping them off with a clean dry cloth.

**Vehicle Jump Starts.** Follow the procedures described below in making jump starts:

*a.* Make sure that both the "live" and the "dead" batteries have the same rated voltage and the same type of electrical ground systems. Check this by looking at the battery terminals. The terminal marked "−", "N", "NEG", or "negative" should have a wire running to the car's frame or engine block.

*b.* Make sure that the "dead" battery isn't frozen. Electrical current from a live battery could cause the dead one to explode, either from too much pressure or from a hydrogen gas detonation. If you're not sure whether the dead battery is frozen or not, our advice is don't try to jump start.

*c.* Bring both vehicles close together but not touching; you may cause sparks or short circuit the good battery if they touch during the jump start.

*d.* Keep the "booster" vehicle engine running, turn off all accessory switches in the "dead" vehicle, set both parking brakes, and don't stand between the two vehicles.

*e.* Remove the well caps from both batteries to provide adequate ventilation for hydrogen gas generated by the battery; cover the wells of each battery with two layers of cloth. (This provides better dissipation of the hydrogen gas and minimizes danger from sparks.)

*f.* Find the "positive" terminal of both batteries. This will be marked on or near the terminal post with either a "P," "POS," "Positive," or a "+" mark. Connect one cable clip to the positive terminal of the live battery and the other clip on the same cable to the positive terminal of the dead battery.

*g.* Connect one clip to the live battery's negative terminal and the other end of the cable to the frame of the "dead" vehicle as far from the battery as cable stretch will allow. This will help prevent any sparks from igniting the hydrogen gas.

*h.* Start the "dead" car's engine and disconnect the two cables in reverse order. Remove cloths from well holes and replace vent caps. Aluminum cables get very hot during a jump start, so allow time for them to cool before putting them away.

Exercises (467):

1. State the proper procedures for making emergency repairs for the following:
   a. Broken hydraulic brake line.
   b. Punctured gas tank.
   c. Broken fan belt.
   d. Vapor lock.
   e. Broken fuel line.
   f. Wet ignition.
2. When jump-starting two vehicles, why shouldn't vehicles touch?
3. Why should the negative side of jumper cables be as far away from the battery as the cable will allow?
4. After the "dead" car's engine starts (during a jump start), how must the battery cables be disconnected?

**468. State precautions and requirements for operating the aerial bucket truck and identify particular controls with locations and functions.**

**Operator Safety.** Because of the advanced hydraulic design and built-in safety features of today's bucket trucks, very little training or skill is needed to safely operate these trucks. However, any truck used to lift personnel is dangerous in the hands of careless or untrained operators. Even after training, in many cases, an operator has admitted being aware that the booms or some part of the truck were not operating properly. If, when operating the boom, you sense anything different, such as hearing noises or feeling unusual movement, STOP at once and resolve the problem.

3. List five safety precautions you should follow when operating the bucket truck.

4. Who is allowed to operate the bucket truck in the Air Force?

5. Where are the auxiliary controls located?

**469. Clarify particular purposes, precautions, and operations relating to the line maintenance truck.**

**Line Truck.** The line truck is used for construction and maintenance of electrical distribution lines. Most line trucks have a compartmental body, a power-driven winch, capstan, tow hooks, a boom, and body support jacks.

*Compartments.* There are bins on the line truck for your tools, equipment, and materials. Keep each item in its place. You should carry at least a one-day supply of hardware, such as bolts, lag screws, connectors, and tape. The equipment needed for electric line work will also be stored on the line truck.

*Power-driven winch.* The winch is operated through the truck power takeoff. Most line trucks have two winch drums. One is located in front and the other is tied in with the boom operation. Both winch drums have automatic brakes which prevent them from turning under a load except when the truck engine is running. Do not exceed the load limitations of the truck and winch line. The manufacturer provides a load capacity chart. The winch will safely lift 15,000 pounds with the cable on bare drum wrap layer and 6,000 pounds with a full drum. For loads that are less than 10,000 pounds, 1/2-inch wire rope will be sufficient. When lifting loads over 10,000 pounds, use 5/8 IWRC 6 x 19 VHS cable. Avoid stacking the winch line and jerking the load.

*Boom.* The boom and winch are used to raise the set, pull and lower poles; load and unload poles from the pole trailer; and load, unload, raise, or lower pole line equipment such as transformers. Read and understand all operating instructions before you operate the boom or any other part of the truck. The operation of the line truck can be extremely hazardous if you don't know what you are doing. All winch and boom operations must have at least two persons—an operator and a spotter who give signals.

Position the truck to work on the high side when parked on a crown or slope. Avoid soft ground and overhead obstructions. Set the parking brake. To engage the power takeoff (PTO) with standard transmission, push in the clutch, place in neutral, engage the PTO, and release the clutch. To engage the PTO if your truck has a transfer case, push in the clutch, put the transfer case in neutral, and engage the PTO. Put transmission in fourth gear and let out the clutch.

Never operate the boom without the jacks down. The jacks are lowered until the tires are almost off the ground. The truck bed is leveled by raising the high side jacks. Level the truck to within 15-percent grade (8½°) for lifting to prevent boom side overload. If there is a question about soft ground, hot asphalt, or weak pavement, then use planks of sufficient area and strength under the jack pads. Some trucks are equipped with a safety switch that prevents boom operation if the jacks are not all the way down. Check the operator's manual for override procedures if they become necessary.

Observe the following precautions when operating the boom:

- Do not operate the boom when winds exceed 30 mph (26 knots).
- Do not operate steel booms within 15 feet of energized overhead lines.
- Do not pull poles out of ground with derrick booms.
- Do not pull side loads with the boom.
- When dragging poles, line up boom with winch cable.
- Do not pull stumps with boom and winch (use a pole jack).
- Do not rock pole with boom to loosen it in the hole.

*Capstan.* The capstan is used for raising loads like transformers, pulling slack in conductors, or holding a strain. Wind the rope on the capstan in a clockwise direction, as shown in figure 7-16, with the load end next to the truck. Keep the direction of the load at a 90° angle to the capstan so the rope will not climb the flange or bind at the turns. Vary the number of turns of rope from three to six or more, depending on the weight of the load.

The capstan turns clockwise to raise a load, and it stops for lowering heavy loads. To pick up a load, gradually increase the strain on the free end of the rope until the load is being reeled in at the desired rate. Lessen the strain to slow or stop the load pickup.

Always keep the free end of the rope in the clear. Do not stand on the free end or allow it to tangle around your feet. A wet rope sticks, slips, or binds, and makes lowering or holding a load difficult. An oily rope slips too fast, allowing a load to lower too fast.

**Exercises (469):**

1. Name three items of equipment found on the line truck used for construction and maintenance.

2. How is the power supplied to operate the line truck winch and boom?

3. How is the winch drum prevented from turning under a load?

This one simple and basic caution, if heeded, could have prevented many of the most serious bucket truck accidents. It is strongly recommended that you and all bucket truck operators follow these simple rules for safe operation and reduction of "downtime" from damaged equipment:

*a*. Allow only qualified operators to operate the controls.

*b*. Operators must be thoroughly acquainted with the operating instructions and limitations of the bucket truck.

*c*. Lubricate and inspect the truck and attached equipment at regular intervals.

*d*. Allow repairs and adjustments to be made only by qualified personnel.

*e*. Do not exceed personnel basket weight limitation.

*f*. Set truck's parking brakes before operating booms.

*g*. Check the complete truck and attached equipment for visible defects or loose objects.

*h*. Check insulated boom for cleanliness and moisture before operating it near energized lines.

*i*. Do not operate boom unless truck is on solid ground and outriggers are extended properly.

*j*. Be sure outrigger lock valves are closed while operating the boom.

*k*. Operate all controls slowly for smooth bucket movements.

*l*. Always use safety belts when operating the bucket.

*m*. Try to avoid maximum outward extension of the booms.

*n*. Do not allow the bucket to come in contact with a fixed object; set in cradle only.

The preceding material represents some basic safety rules that all operators should follow for maximum safe operation of the bucket truck. Remember that your truck cannot protect or service itself. It is up to the operators to insure that the truck stays in good condition.

**Setting Up the Truck.** Position the truck so that the working area is within the reach of the booms. If the truck is positioned on a sloping surface, locate the work to avoid extending the booms to their maximum reach on the downhill side.

Once the truck is in position, operators perform the following steps:

(1) Engage the emergency brake.

(2) Engage power take-off in accordance with the operation and maintenance manual.

(3) Open the shutoff valves for outriggers located at the rear of the truck.

(4) Hold control handle in the down position and lower the outriggers far enough to raise the truck body (not rear tires) 2 inches.

(5) After all outriggers are firmly in place, close all shutoff valves.

(6) Unlatch the upper boom holddown device and remove the band; then pull the locking pin holding the lower boom. (The booms of the truck are now ready for use.)

**Operation of the Aerial Basket.** The operator should mount the basket and put on the safety belt while insuring that the rider does the same. To operate the booms, you must press the trigger on the underside of the control head handgrip. If you move the control head handle horizontally (backwards and forward), this will cause movement of the lower boom: forward to raise, backward to lower. If you move the handle vertically (up and down), this will cause movement of the upper boom: up to raise, down to lower. Rotation of the handgrip will cause rotation of the turntable. Any combination of these movements may be used at the same time to direct basket movement to any point. No movement will result from actuation of the control handle unless the trigger is depressed.

CAUTION: When operating the aerial basket, follow these simple rules:

(1) Always press the trigger on the handgrip before you move the control handle.

(2) Return the control handle to the neutral position before you release the trigger on the handgrip.

(3) Avoid sudden stops or reversal of rotation when turning. (This will prevent stress on the turntable which may cause damage and become a safety hazard to the personnel in the basket.)

(4) Before any rotation of the booms (left or right), raise the lower boom at least 2 feet above its cradle.

**Auxiliary (Secondary) Control.** Three hand-control levers are found on the main hydraulic control valve, near the base of the lower boom. These three levers control the operation of all the basket movements from the ground. No movement of the booms will result from actuation of the levers unless you have depressed the auxiliary palm switch on the turntable or the trigger in the control head handle.

**Folding for Travel.** The booms of the truck must be completely seated in their cradles with no tension remaining on the main boom lifting cable. Always make sure that the upper boom holddown device and the lower boom locking pin are in place before truck movement. If the booms are allowed to bounce in the cradles, the insulated plastic becomes crazed and shattered, eventually allowing the boom to buckle.

In the event of engine or hydraulic system failure, the aerial basket may be returned to the ground level by following the special procedures outlined in the operation and maintenance manual. Never allow anyone to slide down the boom or descend by the use of a handline.

**Vehicle Storage.** If the bucket truck is stored outdoors, you must protect the basket from the weather with a waterproof canvas cover when the basket is not in use. Remember, this basket serves to help insulate the operator from energized electrical circuits and the ground. Take good care of it.

**Exercises (468):**

1. What precautions should be observed when the bucket truck is positioned on a sloping surface?

2. What movement develops when the control head handle is moved forward with the trigger depressed?

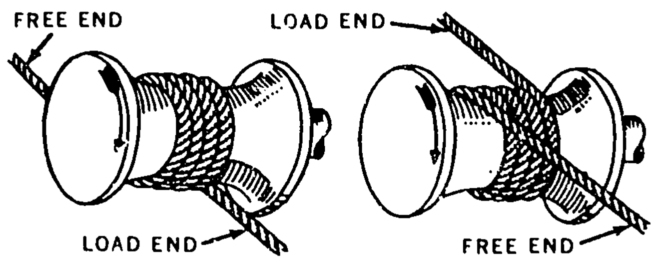


Figure 7-16. Capstan.

4. The boom will not be operated when winds exceed ____________ miles per hour.

5. What is the purpose of the capstan?

**470. Name the types of convoys; state their advantage, disadvantages, and composition; and clarify the scheduling of halts.**

**Types of Convoys.** A convoy is the movement of a group of motor vehicles under the control of a designated individual. In many cases, a convoy is called a motor march. These two terms mean the same thing. Its purpose is to make it easier to coordinate the movement of personnel and material.

There are three kinds of convoys: normal convoys, hazardous convoys, and convoys transporting classified equipment. The normal convoy is made up of general purpose vehicles that can maintain normal speeds on the highway. Hazardous convoys are made up of large. bulky motorized equipment which is too wide, long, or slow to travel at normal highway speeds. Convoys transporting classified equipment may have normal convoy vehicles or hazardous convoy vehicles such as missile hauling trailers. Most of the time, convoys with classified equipment are small and have only one transport vehicle with the necessary escorts.

Three types of marches may be used: close column, open column, and infiltration. The difference between these marches is mostly vehicle spacing. Densities and speeds will vary with such factors as weather, tactical situations, enemy capability, condition and type of road, vehicular maintenance, and types of vehicle.

*Close column march.* Close column march formations are used when in blackout conditions or in congested areas. Elements of the march are grouped as compactly as possible to reduce road space to a minimum. Vehicles in close column follow each other at the minimum distance which safety, traffic conditions, and the tactical situation will permit. For planning purposes, figure that vehicles move at a rate of 10 miles in the hour ("in the hour" refers to distance covered and not miles per hour speedometer readings) with a density of 67 vehicles per mile of road.

The advantage of the close column march is the full traffic capacity of the road or traffic lane that can be used, since road space is reduced to the minimum required for safe driving. Column control and intracolumn communications are better, and fewer guides, escorts, and markers are needed.

Some of the disadvantages are that close column formations do not provide dispersion for passive protection against enemy observation and attack. The strength and type of organization are readily apparent to hostile observation. Vehicles may arrive at loading and unloading terminals more rapidly than they can be handled. Careful scheduling and rigid control of traffic are necessary to avoid blocking intersections. Greater driver fatigue is generally experienced in close column than in other marches. Use of the highway by other traffic is severely limited.

*Open column march.* An open column march is used during daylight moves most of the time. The distance between elements is increased to gain a greater degree of protection from hostile action and to allow other traffic to use the highway at the same time. For planning purposes, figure that vehicles will move at a rate of 15 miles in the hour with a density of 20 vehicles per mile of roadway.

The advantages of open column formation is that they offer some passive protection from enemy observation and action, allow greater speeds with more safety, permit greater flexibility in moves, and reduce driver fatigue.

The disadvantages of open column formations are the difficulty in commanding and controlling them. Abnormal gaps make it hard for drivers to maintain prescribed spacing. Open column formations also permit less traffic volume on a road than more compact formations. In comparison with infiltration, open columns have less secrecy and are not as well adapted to passive defense.

*Infiltration.* Infiltration is used when maximum secrecy, deception, and dispersion are needed. This type of movement involves the dispatch of vehicles to a predetermined destination over one or more routes individually or in small groups at irregular intervals and at irregular rates of march. To an observer, an infiltration move looks like ordinary casual traffic. Vehicles should normally be dispatched so as to produce an average density not to exceed eight units per mile. It is suitable for daylight moves, movement in congested areas, and on routes which cross heavily traveled roads.

Advantages of infiltration type marches are that they give the best possible defense against hostile observation and attack. Under light traffic conditions, movement of the individual vehicle is not materially affected by other vehicles in the move but is limited only by orders, road capability, vehicle mobility, and the training, experience, and physical condition of the drivers. Higher speeds by individual vehicles may be used with this type of

movement. Since traffic density is light, cross traffic may move without excessive interference. A unit may be moved by infiltration over a route on which traffic is too heavy to permit movement to be made in a single unit or column.

The disadvantages are the length of time it takes to complete an infiltration march in comparison to the other types of marches. Thus, in spite of a higher rate of march, the total road clearance time for a move may be longer. More importantly, because of extended distance between vehicles, internal control of the march is difficult. Drivers are usually unable to regulate their movements by the vehicle ahead, and careful marking of the route is necessary to prevent drivers from getting lost. If drivers operate alone, a more detailed briefing is required. Maintenance, refueling, and messing are sometimes difficult to arrange. There is a danger that vehicles may bunch up. Due to relaxed control, tactical employment of the unit may be difficult until the march is completed.

**Internal Composition of Convoys.** Every convoy is made up of three internal elements or parts: head, main body, and trail, with larger convoys having detached parties.

*Head*. The head is the first element of the column in the order of march. The lead vehicle should contain the convoy commander, who is there to handle any problems that occur at the head of the column.

The lead vehicle is designated as the pace setter. The pace setter sets the pace to comply with the rate of march. The maximum pace is controlled by the speed of the slowest vehicle in the march.

*Main Body*. The main body of the march follows the head and is made up of the vehicles carrying troops, equipment, and supplies. In large convoys this part can be subdivided into smaller segments with subdivision commanders.

Slower vehicles should be placed near the head of the column. This arrangement serves as a governor on the faster vehicles and prevents large gaps from developing between elements. If the march is divided into small segments, elements are grouped with the faster vehicles at the head. Thus, as the march moves, gaps between the subdivisions develop and will allow the local traffic to move with greater ease around the convoy.

*Trail*. The trail is the last element of the march. A command designated representative prevents straggling and maintains discipline. Maintenance and medical personnel are included in the trail. The trail commander also makes sure that traffic from the rear is warned of the convoy ahead and picks up guides and markers. In case of breakdowns, the trail personnel make repairs, arrange for towing, or see that the vehicle is properly attended until disposition of vehicle and cargo can be effected.

*Detached Parties*. Advance parties are detailed to locate and arrange for campsites; for loading and parking; and for supplies, rations, water, fuel, and medical attendance before the convoy arrives. The advance parties are also responsible for reconnaissance and posting guides, traffic control personnel, and route markers as needed.

The followup detachment is designated to inspect the camp areas and other halt sites after the march has left. This party may also pick up guides, guards, and markers. They al[illegible] rovide for the disposition of the dead or wounded and of disabled vehicles.

**Halts.** Halts are made for purposes of rest, personal comfort and relief, messing, refueling, maintenance and inspection of equipment, and allowing other traffic to pass.

Routine short halts will be made at the discretion of the commander. Short halts should be made for 10 minutes after every 110 minutes of running time. Long halts for messing, refueling, and overnight stays should already be designated on maps before the march leaves.

The location for scheduled halts should be selected in advance and plotted on the map. Comfort of personnel and servicing facilities for vehicles are important considerations in selecting sites for long hal[illegible] If a march starts from a populous area, its first halt should be delayed, when practical, until a rural area is reached to facilitate relief of personnel. Convoys should be stopped at a point that will give a minimum of 200 yards of clear visibility to the front and rear of the column. Guards, warning flags, caution lights, or flares should be posted in the front and to the rear of the convoy if it presents a hazard to passing traffic.

**Exercises (470):**

1. List the three types of convoy and one advantage and one disadvantage of each.

2. List the three main elements of a convoy.

3. Which unit determines the rate of march for a convoy?

4. What is a detached party?

5. Why are halts made during a convoy movement?

6. How often should shorter halts be scheduled for a convoy?

7. What are two things to consider when scheduling long halts?

**471. State factors to be considered, sources and kinds of information, and the importance of route reconnaissance in planning convoy movements.**

The first step in preparing for a convoy movement is planning. In most cases, the care with which the planning is done determines how efficiently and smoothly the movement is made. There are several things to consider when planning and coordinating your movement. Among these are factors affecting the move; escort, markings, and permit requirements; route reconnaissance; type of march to be used; and the preparation of march graphs.

**General Planning Factors.** There are a number of factors that determine the amount of planning needed when a convoy movement is to be made. When convoy movements are being formulated, purpose of the convoy, quantity and type of cargo to be hauled, loading point, destination, and arrival time must be known. This information is usually obtained from orders and instructions issued by higher authorities.

Next, determine the number and type of vehicles which are necessary. This can be decided after the amount and type of cargo are known. The number of personnel necessary depends to a great extent upon the number and type of vehicles needed.

Now determine the supplies that are required. The number of vehicles, distance to travel, and personnel involved are the factors to be considered. When all this has been done, you should answer the following questions:

- What is the best route to take?
- Where are halts to be made?
- At what speed will the convoy travel?
- Where will fuel, oil, and other supplies be obtained?

However, if you are not familiar with the area of movement, do not attempt to answer these questions until you have made a route reconnaissance. You will then be able to answer the preceding questions regarding the route. After answering these questions, decide which type of march you will use and arrange the convoy accordingly. You must also arrange for convoy control.

Finally, most movements within the continental United States or its territories are coordinated with the civil traffic authorities before they are started. Be sure to get all the necessary permits and clearances required from the civil authorities as early as possible.

**Route Reconnaissance.** Route reconnaissance simply means to survey a route over which a convoy movement will be made. This survey is used to gather needed information concerning the route and adjacent areas for planning the move. Reconnaissance should be made before and during any motor move.

You may obtain basic information from maps (either standard highway or military), personal knowledge, and from reports furnished by engineers, Security Police, and weather forecasters. Within the continental limits of the United States and in most oversea areas, you will find well marked routes and traffic personnel available. But even so, you may make a limited reconnaissance to prevent accidents or delays. In combat areas, you must make a more thorough reconnaissance—lack of information there may prove disasterous both to personnel and equipment.

What information should you obtain from a reconnaissance? If your reconnaissance is thorough, it should provide you with the following information:

*a*. The location and nature of major routes in the area.

*b*. The location and characteristics of major road junctions.

*c*. The location and character of detours or bypasses.

*d*. The time and distance measurements between major points.

*e*. The types of road surface and the condition of roadway and shoulders.

*f*. The width of each roadway and the number of traffic lanes available for movement in each direction.

*g*. The maximum grades (percent).

*h*. Limiting physical features of the available routes (clearances, heights, loads, and widths).

*i*. Facilities providing fuel, repairs, rations, water, and other supplies.

*j*. Availability of medical facilities in the area.

*k*. The traffic density at critical points.

*l*. The variations in traffic density.

*m*. The location of critical points (bottlenecks, points needing traffic control, or highway regulation).

*n*. Availability and type of communications facilities.

*o*. Traffic control devices and their locations.

*p*. Types of traffic controls that are or can be used.

*q*. The locations of potential hazards (lack of roadways, ice and snow, steep grades, etc.).

*r*. The locations and characteristics of fords.

*s*. The routes which afford maximum protection from hostile ground or air attack.

*t*. Road and bridge construction that may be required.

*u*. Sites that may be adequate for dumps or depots.

**Exercises (471):**

1. How are the number and type of vehicles determined in a convoy move?

2. Why is route reconnaissance important in a move?

3. What factor determines the number of personnel needed for a convoy?

4. Complete the following statements (one word in each blank):

   Basic information to be used in route reconnaissance may be obtained from highway ________, personal knowledge, and reports furnished by engineers, Security Police, and weather ________.

   A thorough reconnaissance usually reveals information concerning the location of ________ supply facilities and critical ________ en route.

**472. Given a march graph, determine distance and time factors concerning a convoy movement.**

**March Graphs.** A march graph is a time-distance diagram used in planning, controlling, and recording the progress of a convoy over a given route. It gives a visual picture of a movement and thus shows possible conflicts and congestion before they occur.

March graphs may be used for an individual vehicle, a small unit, or a large motor movement. They may show the movement at one or several columns traveling at different speeds over one or more routes.

Before preparing a march graph, determine the following information concerning the route and movement:

*a*. Distance from starting point to destination.

*b*. Route characteristics such as road surface, curves, populated areas, intersections, number of lanes, etc.

*c*. Reasonable speed for the convoy to travel.

*d*. Where halts will be made, and the time spent for each.

*e*. Checkpoints along the route.

*f*. Rate of march.

*g*. The time required to make the move (by dividing the distance by the rate of march).

When you have the required information, you are ready to prepare a march graph. As we cover the preparation of a march graph, refer to figure 7-17 and check each item as we discuss it.

The first requirement is that the graph paper contains enough squares to plot the distance and time involved in the move. Across the bottom of the graph paper, starting at the left and progressing to the right, a time scale is inserted. A scale of distance, usually in miles, is then placed up the left side of the paper starting at the bottom.

After the time and distance scales are established, the selected route is added on the side of the graph. The names of towns, intersections, highway regulation points, and traffic control posts along the route are shown at their proper locations on the route. This is done by the use of a diagrammatic strip map.

Next, the movement is plotted on the prepared graph. For example, in figure 7-17, a unit is to march from Mt. Royal to a point 5 miles beyond Travistock. Scheduled departure time is 0700 and the column is planned to proceed at the rate of 15 miles in the hour.

A dot is placed on the graph at the point where the line representing the place of departure intersects the line

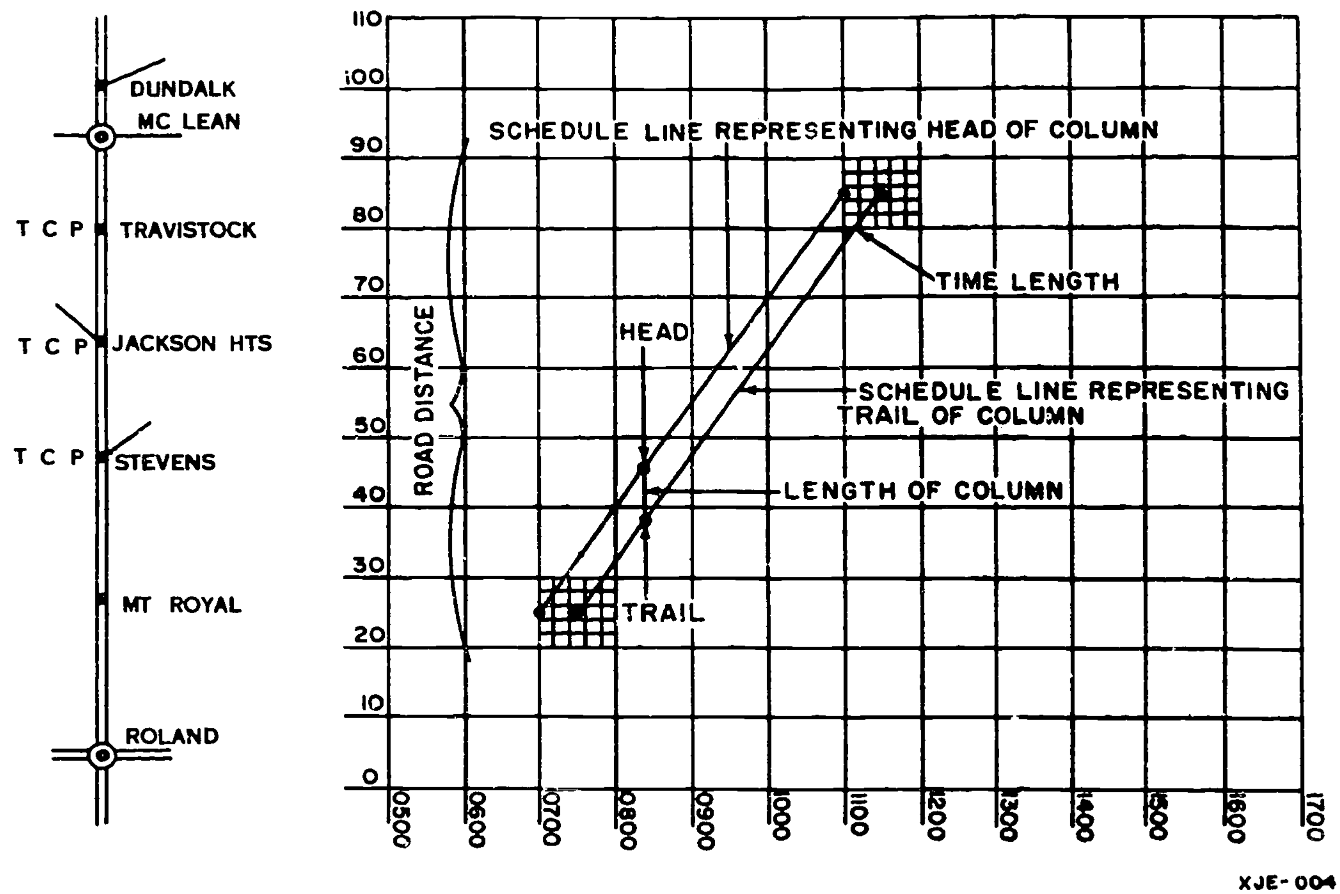


Figure 7–17. March graph.

representing the hour of departure. Another dot is placed on the graph at the point where the line representing the destination intersects the line representing the hour the head of the column is scheduled to arrive. A straight line is drawn to connect these two dots. This line represents the schedule on which the head of the column travels and indicates when it should reach any point en route.

In addition to scheduling the head of a column, the end of the column (the trail) may also be scheduled on a march graph. For example, in figure 7-17 the head of the column was scheduled to leave Mt. Royal at 0700 hours and the last vehicle of the convoy was scheduled to leave Mt. Royal at 0730.

After the head and trail of a column have been scheduled on a march graph, the length of the column can be determined. This is done by drawing a vertical line connecting the head and trail lines. This vertical line is measured and applied to the scale of miles, thereby giving the overall length of the column.

**Exercises (472):**

Using the march graph in figure 7-17, determine the following planning (distance and time) factors.

1. What is the distance the convoy will travel?

2. When should the convoy head arrive?

3. When should the convoy trail arrive?

4. How long (miles) is the convoy column?

5. Where should the convoy head be at 0930?

**473. State and, from given situations, determine convoy communications methods.**

**Convoy Communications.** Intracolumn communications help provide convoy control. Sign messages from the front of the column may be written on a board and posted on the driving side of the road or displayed by a guide. Such messages are then noted by the drivers as they pass the signboard.

Written messages directed to a unit or vehicle in the column may be delivered by a messenger or given to a guide stationed along the route who will transfer it to the proper vehicle.

Two-way sets may be located in the control cars of the commander and at the head and trail. When supplemented by receivers in other vehicles in the column, they provide the best intracolumn communications and afford maximum control of a column.

Whistles and other audible signaling devices (horn, siren, etc.) can be used as a means of transmitting a command to a column when a code has been established.

Visual hand and arm signals constitute another means of march communication. Column control signals may be given from the cab of a vehicle or by a person standing on the road. The meaning of the standard hand and arm signals used for convoy control is contained in AFM 77-2, *Manual for the Wheeled Vehicle Driver*.

**Exercises (473):**

1. List four methods of communicating between personnel within a convoy.

2. A message for the driver of the fifth vehicle in the march could be delivered by what means?

3. Part of the convoy is to be rerouted a short distance. There is no radio communications within the convoy. How could the drivers be notified?

**474. State responsibilities, procedures, and sources of information in the coordination and application of control measures, escort requirements, and permits for convoy movements.**

**Coordination/Escort Requirements for Normal Convoys.** Normal convoy movements outside the local area consisting of 10 or more vehicles organized as a column are coordinated with civil traffic authorities by higher headquarters. This also applies to movements of 10 or more vehicles dispatched over the same route to the same destination during a 1-hour period. Arrangements with civil authorities for local movements are handled by the base transportation officer in coordination with the Security Police officer.

**Special Procedures and Escort Requirements for Hazardous Convoys.** Normal convoys are protected in both the front and the rear by escort vehicles. These escort vehicles should be equipped with red warning lights, flares, and other emergency equipment. These vehicles travel far enough in front of and behind the convoy to give adequate warning to all approaching traffic.

Hazardous convoys require special markings, red flags, and lights to make them readily identifiable and to reduce their danger to other traffic. Special markings and

procedures also apply to all vehicles transporting explosives. Each truck carrying explosives or ammunition is properly marked with explosive warning signs. The word "explosives" or "dangerous" as determined by the class of explosives is exhibited in letters at least 6 inches high on reflectorized placards. These placards are posted on the front, rear, and both sides of every vehicle. When two or more trucks carrying explosives are traveling together, a minimum distance of 300 feet is maintained between vehicles. Department of Transportation regulations govern the transportation of explosives on public highways. Specific safety precautions for the transportation of explosives are given in AFM 127–100, *Explosive Safety Standards*.

Escort vehicles lead and follow these convoys. Normally, escort vehicles are equipped with and display rotating red flashing beacons and will also keep their headlights on. Suitable signs (preferably luminous) are displayed, indicating that a convoy follows or is ahead. Radio communications are used, when available, to facilitate normal communications and the immediate adoption of emergency procedures.

Other vehicles in the convoy will have headlights and running lights turned on at all times. All overhanging and projecting equipment is marked with red flags during daylight when visibility is good; red and amber lights are used during periods of poor visibility and at night.

The vehicle operations officer and the convoy commander are responsible for insuring that these convoys are equipped for all conditions expected. The coordination with civil authorities for the movement of hazardous convoys is carried out by higher headquarters.

**Special Procedures Requirements for Classified Convoys.** Small classified convoys of vehicles not exceeding legal limitations on size or weight can be coordinated locally. However, oversize classified equipment requires the same coordination as any other hazardous convoy.

Convoys with classified equipment are under the direct control of a security officer who may also act as convoy commander. Also, escorts leading and following the convoy are security guards. The number of guards and their locations in the convoy are determined by the commander ordering the movement. Driver personnel must have security clearances.

**Procedures in Coordination and Obtaining Permits for Convoys.** The first thing is to determine whether or not the vehicle is oversize or overweight, thereby requiring a clearance. Each State has established its own limitations on vehicle widths, heights, lengths, weights, and axle loadings. Since these limitations vary considerably from State to State, you must be familiar with those for all the States in which your vehicles operate. You can get this information by checking State laws or by asking the appropriate highway officials. However, there is a simpler method. The American Trucking Association, Inc., publishes a consolidated chart that shows current information on vehicle sizes and weights and other related matters for highway carriers. This is not an official Air Force publication, but it is used for military vehicle movements and commercial carriers.

The Director of Transportation and Supply of the appropriate air logistics center (ALC) is the representative designated to secure permits for military vehicle movements. He determines whether or not the movement by highway is essential to national security. When appropriate, he makes all the necessary requests and certifications to the authorities of the States involved.

In some cases, there is a recurring need for oversize, overweight, and special movements of military vehicles within a limited area. The director (mentioned above) coordinates and arranges for formal agreements with State and local civil authorities for such movements. Copies of these agreements are furnished to State officials, local military officials, and the Director of Transportation, Headquarters USAF. When a movement is to be made under an agreement, the local base transportation officer notifies the civil authorities of the move and obtains the necessary permits.

When an essential movement which is not covered by an agreement must be made, the local base transportation officer will request the appropriate ALC Director of Transportation and Supply to negotiate for the required permits. The request should be prepared on DD Form 1265, Request for Convoy Clearance, or on DD Form 1266, Request for Special Hauling Permit. These forms furnish all the information normally needed for negotiation. The information to be furnished for oversize or overweight vehicles includes, as a minimum, the following:

*a*. Type of equipment with the manufacturer's name, if available, and pertinent accessories; gross weight; axle or track loads and spacing; and the height, width, and length of the vehicle, both loaded and unloaded.

*b*. Origin and destination of the movement.

*c*. Proposed date and time of the movement.

*d*. Nature of the cargo (within security limitations).

In addition, reasons must be given why oversize or overweight vehicles or loads cannot be reduced. Also justification must be given as to why highway movement is essential instead of using another mode of transportation.

In urgent cases, applications for permits can be made by electrical communications means. These message requests should give the required information in the numerical order given on the DD forms and should be confirmed through the submission of the applicable form.

Except in an emergency, all permits and clearances necessary for convoy movements are obtained at least 24 hours before the movement. Also, if civil police escorts or traffic personnel are needed, arrangements for them must be made at least 24 hours ahead of time.

**Exercises (474):**

1. What is the best source of information pertaining to State laws concerning overweight or oversize vehicles for movement over highways?

2. Name three officials that are given a copy of a written formal agreement for oversize, overweight, and special movement of military vehicles.

3. You have a movement which involves 19 vehicles. All of the vehicles will reach the same destination within a 1-hour period. Who is responsible for the initial coordination?

4. Who has the direct control of vehicles transporting classified equipment?

5. What forms are used for requesting permits for essential oversize convoy movements not covered by formal agreements with appropriate civil authorities?

# ANSWERS FOR EXERCISES

CHAPTER 1

**Reference**

400 – 1. The major parts of a DC motor include the field assembly, frame, armature, brush assembly, and endbells.
400 – 2. The armature is the rotating part of a DC motor, while the commutator segments connect to the external circuit.
400 – 3. They are bolted to the inside of the frame.
400 – 4. The field coils are placed around the pole pieces.
400 – 5. By means of brushes.
400 – 6. To keep the armature in position.

401 – 1. Attract.
401 – 2. The direction in which the current flows through the winding of an electromagnet determines the polarity.
401 – 3. Left-hand rule.
401 – 4. Commutator.
401 – 5. The attracting or repelling force of magnetic fields.
401 – 6. Series, shunt, and compound.
401 – 7. a. Series; b. shunt; c. compound.
401 – 8. Series.

402 – 1. Stator, rotor, and endbells.
402 – 2. The squirrel-cage rotor is made up of a laminated steel core, rotor bars, end rings and shaft.
402 – 3. House the bearings, align the rotor and shaft, and complete the frame.
402 – 4. Wound rotor.
402 – 5. The rotor is the rotating part of a 3$\phi$ motor.
402 – 6. Provides an attachment point for the supply voltage.
402 – 7. To reduce eddy currents.
402 – 8. For variable speed control and low starting current.

403 – 1. Rotating magnetic field.
403 – 2. Slip.
403 – 3. (1) The difference in amount of current flow in the 3$\phi$ power, (2) reversal in direction of current flow, and (3) the arrangement of the field winding in the stator.
403 – 4.

$$\text{RPM} = \frac{50 \times 120}{4} 1500.$$

403 – 5. 2–5 percent.
403 – 6. Frequency and number of poles.
403 – 7. The motor speed increases.
403 – 8. 25-percent slip.

404 – 1. Wye or delta.
404 – 2. Y, $\Delta$.
404 – 3. Series.
404 – 4. Parallel.
404 – 5. 10, 11, 12.
404 – 6. 1, 2, 3.
404 – 7. 3 leads for single voltage and 9 leads for a dual-voltage motor.

405 – 1. Run winding and start winding.
405 – 2. To deenergize the start windings after the rotor reaches a predetermined rpm.
405 – 3. The centrifugal switch is connected in series with the start winding.
405 – 4. It increases starting torque.
405 – 5. 75 percent of full speed.
405 – 6. Permanent/split capacitor motor.
405 – 7. Small fans, timers, and various light-load control devices.
405 – 8. It is used in place of a start winding.

406 – 1. (1) Repulsion motor, (2) repulsion-start induction-run, (3) repulsion-induction motor.
406 – 2. High starting torque and low current draw.
406 – 3. The simple repulsion motor.
406 – 4. They improve the power factor during the starting period.
406 – 5. Because of the low rate of current flow in the squirrel-cage windings at low speeds.
406 – 6. The increased current flow in the squirrel-cage windings when the motor reaches operating speed.
406 – 7. The load. The motor operates at low speed with a heavy load and at high speed with a light load.
406 – 8. Universal motor.

407 – 1. Two. 407 -2. Series.
407 – 3. Parallel.
407 – 4. Leads 5 and 8.

408 – 1. Manual and magnetic.
408 – 2. A manual controller is a device mechanically operated to control a motor from a single point.
408 – 3. In series with the main contacts.
408 – 4. Overload devices.
408 – 5. L1, L2, L3.
408 – 6. A drum switch is used to change the rotation of a motor.

409 – 1. The contactor and the overload relay.
409 – 2. The operating coil.
409 – 3. To prevent contact chatter.
409 – 4. Thermal and magnetic.
409 – 5. Bimetallic and melting alloy.
409 – 6. By checking the motor data plate.

410 – 1. Load circuit and control circuit.
410 – 2. Auxiliary contacts.
410 – 3. Three. Each ungrounded phase must have an overload device.
410 – 4. Float switch, pressure switch, thermostat, and photoelectric cells are common automatic controls used to operate magnetic starters.
410 – 5. It is the portion of the starter that starts, stops, controls, and protects the motor.

411 – 1. (1) Physical location, (2) ambient temperature, (3) duty, (4) bearings, (5) voltage, (6) mechanical connection to load, and (7) motor data plate.
411 – 2. Splash-proof.
411 – 3. 40(de C.
411 – 4. Ball bearings or roller bearings.
411 – 5. (1) Maker's name, (2) rated volts and full-load amperes, (3) rated frequency and number of phases, (4) rated temperature rise, (5) rated full-load speed, (6) time rating, (7) code letter, and (8) rated horsepower.
411 – 6. Outdoors, (it can be exposed to the weather).

412 – 1. Visually inspect excessive wear, the gears, sprockets, coupling, belt tension, pulleys and belt alignment and tension.
412 – 2. 25 psi.
412 – 3. Can cause motor bearings to overheat and cause bearing failure, excessive wear to the bearing, and seizures.

412 – 4. Connections should be clean and tight. Check all wiring for discoloration.

413 – 1. (1) Overload, (2) loss of power, (3) driven machine blocked, (4) worn bearings, and (5) bad connections.
413 – 2. An ammeter.
413 – 3. By using a soldering gun to restore the circuit.
413 – 4. By disconnecting the motor from its load and rotating the rotor shaft of the motor by hand.
413 – 5. By adding fiber space washers.

414 – 1. Open, grounded, and shorted circuits.
414 – 2. At any point between the power source and the rotor.
414 – 3. In order to determine whether a ground exists in the motor or on the conduit.
414 – 4. When the ground does not exist in the conduit from the stator to the motor.
414 – 5. By checking across conductors with the power off.
414 – 6. Continuity across any two conductors.
414 – 7. Continuity between any combination of lead numbers other than those which form a winding.
414 – 8. The motor will slow down under load; it will have low starting torque and signs of overheating.

415 – 1. (1) a.
(2) a.
(3) c.
(4) c.
(5) e.
(6) b.
(7) d.
(8) b.
(9) d.
(10) a.
(11) e.
(12) e.

CHAPTER 2

416 – 1. The use of the location.
416 – 2. Danger is eminent at any or all times during the normal course of operation.
416 – 3. Danger is not believed present under normal conditions, but is likely to arise from a reasonably foreseeable accidental occurrence.
416 – 4. Gas stations and hospital operating rooms.
416 – 5. Grain elevator, flour mills, and coal pulverizing plants.
416 – 6. Class III.
416 – 7. Class I.

417 – 1. It is usually identified as explosion-proof, dust-proof, or spark-proof, whereas standard is not.
417 – 2. No.
417 – 3. Class I.
417 – 4. Class II.
417 – 5. Spark-proof.

418 – 1. Rigid metal conduit, IMC, or type MI cable.
418 – 2. To minimize sparking.
418 – 3. Five.
418 – 4. Seal-off.
418 – 5. It must be dust ignition-proof.
418 – 6. Reduces costs and minimizes the equipment located in the hazardous area.

419 – 1. T.
419 – 2. T.
419 – 3. T.
419 – 4. F. They should be assembled to their mating bodies.
419 – 5. F. They prevent a close fit and may allow arcs, flames, and sparks to pass through them, causing fires.
419 – 6. F. Never use abrasive material.
419 – 7. T.
419 – 8. T.
419 – 9. T.
419 – 10. T.
419 – 11. T.
419 – 12. T.

420 – 1. T.
420 – 2. T.
420 – 3. F. It should be powered by a low-voltage dry cell battery.
420 – 4. F. It should not be located in a hazardous area unless necessary.
420 – 5. T.

CHAPTER 3

421 – 1. A step up transformer delivers a higher voltage in the secondary than the primary voltage; a step-down transformer delivers a lower voltage to the secondary than the primary voltage.
421 – 2. The core, primary winding, secondary winding, and the case.
421 – 3. Mutual induction.
421 – 4. Distribution and large power transformer.
421 – 5. 24 volts.
421 – 6. Copper losses and core losses.
421 – 7. Silicon steel.
421 – 8. PF = 85 percent.
421 – 9. True power.
421 – 10. Secondary transformer windings connected in parallel deliver the same voltage in each winding; however, the currents of each winding add.
421 – 11. The purpose is a current transformer. The primary winding is connected in series with the circuit in which it is desired to change the current.

422 – 1. T.
422 – 2. F. Current-carrying capability is based on the size of the wire in the coils and the size of the terminal connections.
422 – 3. T.
422 – 4. F. Taps or jumpers are connected on the high voltage windings.
422 – 5. F. All coil leads of the higher voltage windings are marked with the letter "H".
423 – 1. 125 percent of 50 amps equals 62.50 amps. The standard size overcurrent device would be 60 amp.
423 – 2. 112½ KVA.
423 – 3. Delta or wye.
423 – 4. Delta-delta connected for light and power.
423 – 5. Wye-delta connected for light and power.
423 – 6. Every few years.
423 – 7. To assure that all mechanical parts are tight and in their proper places.
423 – 8. To prevent overheating.

424 – 1. Open windings, shorted windings, and grounded windings.
424 – 2. A break in the continuous path of an electrical circuit.
424 – 3. One of the windings is open.
424 – 4. An ohmmeter.
424 – 5. Overheating and low or no voltage output.
424 – 6. When the winding insulation breaks down and the bare wire touches the inside of the transformer case, you have a ground.
424 – 7. Megger.

425 – 1. Voltage.
425 – 2. The series regulator requires only a series regulator element in series with the unregulated power supply. The shunt regulator represents an additional current load in parallel with the load it is regulating, which increases the current requirements of the unregulated power supply.
425 – 3. Two.
425 – 4. When an increase in direct current can no longer cause an increase in flux. Practically no energy can be transferred between primary and secondary windings.
425 – 5. Theater lighting, dimming controls, and motor controls.
425 – 6. Severe waveform distortion.

426 – 1. That of maintaining an essentially constant voltage under various load conditions.
426 – 2. Inspect for proper voltage.
426 – 3. Keep clean by removing any dust and lint, provide proper ventilation and check for proper voltage.
426 – 4. Zero volts.
426 – 5. Replace it.

427 – 1. By passing a current through it in the reverse direction.
427 – 2. The material from which the plates are made and the type of electrolyte.

427 – 3. Ammonium chloride.
427 – 4. A flashlight.
427 – 5. (1) It can be recharged, (2) it can be built to provide greater current, and (3) it is more economical in the long run.
427 – 6. The plates are made of lead and the electrolyte is sulfuric acid.
427 – 7. Its comparative weight with respect to the weight of an equal volume of water.
427 – 8. With a hydrometer.
427 – 9. At temperatures above 80°.
427 – 10. 2.15 volts.
427 – 11. The electrolyte does not participate in the chemical reaction of the battery; it merely provides the conductive path between the positive and negative plates.
427 – 12. 1.30 volts.

428 – 1. For charging more than one battery at a time and when higher voltages are required than a single battery can deliver.
428 – 2. The sum of the two batteries' voltage is increased.
428 – 3. None; amperage capacity is increased.
428 – 4. Ventilation.
428 – 5. Metal, fiberglass, or any nonmetallic material able to resist deteriorating action by an electrolyte.
428 – 6. Mounted on a rack or in trays.
428 – 7. A layer of petroleum jelly.
428 – 8. A stiff brush.
428 – 9. Tap water.
428 – 10. An apron, goggles, and rubber gloves.

429 – 1. Motor generator types and AC-to-DC rectifiers.
429 – 2. Direct current is forced through the battery in the opposite direction from which the current flows during discharge. Acid is driven back into the water solution, thus restoring the electrical energy as chemical energy.
429 – 3. Water is broken down and hydrogen is released at the negative plates and oxygen at the positive plates. These gases bubble up through the electrolyte and collect in the airspace at the top of the cell.
429 – 4. To change AC to DC.
429 – 5. Flammable fumes that could explode are discharged.
429 – 6. Selenium and iron.
429 – 7. Limited to the amount of current, voltage, and heat it can withstand.
429 – 8. They are smaller and cheaper than dry-disc rectifiers.
429 – 9. Current flows in the desired direction during the first half and is blocked during the other half.
429 – 10. Four.
429 – 11. Four.
429 – 12. Capacitor and choke.

430 – 1. Allow proper ventilation and keep the unit clean.
430 – 2. Replace the rectifier.
430 – 3. An oscilloscope.
430 – 4. By feeling.

431 – 1. a. Shorted cell.
b. Open cell.
c. Low specific gravity.
d. Dead cell.
431 – 2. Replace the battery.
431 – 3. In accordance with prescribed directives.
431 – 4. Always connect the ungrounded terminal first; this prevents sparking if your wrench touches the ground or frame while you are tightening the terminal.

432 – 1. They provide a temporary source of light when commerical power is lost.
432 – 2. (1) Rechargeable battery, (2) battery charger, (3) low-voltage incandescent floodlights, and (4) test, monitoring, and control accessories.
432 – 3. 6.
432 – 4. 12.
432 – 5. 25 watts, 6 volts, and sealed beam.
432 – 6. 1000.
432 – 7. The AC relay deenergizes, closing a set of contacts, which provides a path for the battery voltage to energize or turn on the floodlight.
432 – 8. This allows the power to be shut off and the exit lights to still work.
432 – 9. They provide a means of identifying the outside doors to a building.
432 – 10. Incandescent and fluorescent.

433 – 1. It must be able to maintain at least 87½ percent of the system voltage for a period of at least 1½ hours.
433 – 2. Transparent, or translucent.
433 – 3. Independent of regular wiring and in a separate raceway, cable, or box.
433 – 4. The space where the light is out cannot be left totally dark.

434 – 1. Monthly.
434 – 2. CE personnel.
434 – 3. Written record.
434 – 4. Check water level and electrolyte, check charging rate, test for operation, replace lamps, if necessary, and remove any corrosion.
434 – 5. Wash battery terminals with a solution of baking soda and warm water. Apply a small coat of lubricant.
434 – 6. About every 6 months.
434 – 7. Replace it with the same type of battery.
434 – 8. The plug-in type; insert a new one.
434 – 9. (1) Bad fuse, (2) transformer, (3) diode or bridge rectifier.

435 – 1. To turn a piece of equipment on or off.
435 – 2. Manual and automatic.
435 – 3. (1) Toggle switch, (2) rotary switch, (3) pull and turn switch.
435 – 4. (1) Bimetallic blade, (2) helix control, (3) hydraulic control, (4) timers.
435 – 5. A thermostatic metal that coils and uncoils when heat is applied.
435 – 6. Expanding and contracting effect caused by heating two pieces of dissimilar metals.
435 – 7. A capillary tube transfers heat-created pressure to the diaphram.

436 – 1. Coil type and ribbon type.
436 – 2. Surface-cooking type and immersion.
436 – 3. Inside a copper tube or cast in an iron tube.
436 – 4. Nichrome.
436 – 5. Where the material to be heated is dry and the element does not come in contact with anything.
436 – 6. Small appliances such as irons and toasters.
436 – 7. Nichrome.
436 – 8. Discard it.

437 – 1. T.
437 – 2. T.
437 – 3. T.
437 – 4. F. A thermostat acts as the main switch and regulates temperature.
437 – 5. T.
437 – 6. T.
437 – 7. T.

438 – 1. On the nameplate.
438 – 2. By its green color.
438 – 3. 125 percent.
438 – 4. 800 to 16,000 watts.
438 – 5. Upon the kilowatt rating of the range.
438 – 6. 6 or 8.
438 – 7. It must be protected by a 50-amp overcurrent protection device; and all receptacles, switches, and sockets must have a rating of 50 amps.
438 – 8. To prevent possible arcing at the prongs of the male plug and the wall outlet.

439 – 1. Visual inspection.
439 – 2. Continuity.
439 – 3. Check the power supply and the condition of the power cord.
439 – 4. Incorrect or reverse connections.
439 – 5. Replacement of burned-out heating elements.
439 – 6. There are none. They must be replaced.
439 – 7. Dress the contact points with a strip of cardboard or a burnishing tool.
439 – 8. The power connections, switches, and the motor field windings.

440 – 1. Loose connections, burned or pitted contacts, and improper mounting of switches.
440 – 2. By lubricating the contacts and spring mechanism with nonoxide grease.
440 – 3. By adjusting the temperature setting of the control to agree with the temperature recorded in the appliance or equipment being tested.
440 – 4. A good element.

## CHAPTER 4

441 – 1. Corrosion is the gradual destruction of a material by chemical or electrochemical means.
441 – 2. a. Anode—the metal or portion of a metal which is corroded and from which the current leaves.
b. Cathode—the metal or portion of a metal which the current enters.
c. Electrolyte—a solution capable of conducting electricity.
d. Metal circuit—the circuit through metal or a conductor joining the two metals or areas of metal.
441 – 3. Simple cell corrosion takes place where there is moist soil at one point of a substance and soil of a different moisture content at another point.

442 – 1. At the anodic area.
442 – 2. Stray-current corrosion.
442 – 3. General corrosion.
442 – 4. Galvanic corrosion.
442 – 5. Aluminum.
442 – 6. In sea water.
442 – 7. Zero.
442 – 8. Hydrogen.
442 – 9. Because of polarization.
442 – 10. Concentration-cell corrosion.
442 – 11. Steel pipe exposed to clay.
442 – 12. Localized concentration-cell corrosion caused by contact with lumps of clay in a sandy loam backfill.

443 – 1. By reducing the anodic current; cathodic protection.
443 – 2. Direct current.
443 – 3. a. GA.
b. IC.
c. GA or IC.
d. GA.
e. IC.
f. GA.
g. IC.
h. GA.
IC.
j. GA.
k. IC.
l. GA.
m. GA.
n. GA and IC.
o. GA and IC.
p. GA.
q. GA.
r. IC.
s. IC.
t. GA and IC.
u. GA and IC.
v. GA and IC.

444 – 1. To permit free air circulation, keep dust, brush, and grass cleared out.
444 – 2. To prevent birds from nesting and to keep snakes out.
444 – 3. When it becomes cloudy looking.
444 – 4. The pits have been sealed off and the corrosion has stopped or slowed down.
444 – 5. The corrosion is active.
444 – 6. It physically separates a metal structure from the electrolyte.
444 – 7. Corrosion accelerates at bare, damaged spots in coated surfaces because current will concentrate at small areas of bare metal.

445 – 1. A history of the system to include: what, when, and where it was installed, maintenance, and operability of the system.
445 – 2. In the facility jacket folder.
445 – 3. TAB G–8 of the master plan.
445 – 4. In the corrosion engineer's possession.
445 – 5. By placing a colored head pin at each point where there is a leak on a base map installed in the corrosion engineer's office.
445 – 6. (1) c.
(2) a.
(3) b.
(4) d.
(5) d.
(6) b.
(7) c.
(8) a.
(9) a.
(10) d.
(11) b.
(12) c.
445 – 7. The corrosion problems.
445 – 8. The effectiveness of the cathodic protection system.
445 – 9. Pipeline current tests.

446 – 1. We measure our various potentials against the engineer's criteria.
446 – 2. With the reference electrode as close to the structure as possible.
446 – 3. Structure-to-electrolyte potential.
446 – 4. The protective current is applied to the circuit.
446 – 5. The protective current is turned off.
446 – 6. When the entire structure is polarized to at least −0.85 volts.
446 – 7. When bare, poorly-coated or old steel structures are to be protected.
446 – 8. −2.05 volts.

447 – 1. a. Tell how the system is functioning.
b. Discloses any changes in electrical flow.
447 – 2. When the structure cathodic protection system is first installed.
447 – 3. Structure-to-electrolyte measurements.
447 – 4. A high-resistance voltmeter and a copper-copper sulfate half-cell.
447 – 5. The negative terminal of the voltmeter is connected to the structure and the positive terminal to the electrode of a copper-copper sulfate half-cell.
447 – 6. The potential value from the voltmeter.
447 – 7. Outside influences or failure of the cathodic protection system.
447 – 8. A high-resistance connection.
447 – 9. Which lead wire is attached to the anode.
447 – 10. Insert an ammeter into the conductor between the anode and the structure.
447 – 11. Install a permanent pavement insert.
447 – 12. Structure-to-electrolyte measurements.
447 – 13. Test stations.
447 – 14. Thermite welding and crimping.
447 – 15. By means of a thermite weld cap filled with mastic.

448 – 1. The soil's ability to conduct or resist electricity is related to the rate of buried or immersed structure corrosion.
448 – 2. With a Vibroground instrument.
448 – 3. 5 feet.
448 – 4. A depth equal to the pin spacing.
448 – 5. By reversing the DC current or using an AC meter.
448 – 6. By its inverse characteristic, conductivity.
448 – 7. It is used to measure the resistivity of a small sample of electrolyte.
448 – 8. In galvanic anode systems, soil resistivity measurements are used to determine how many and where anodes are needed; in impressed current systems, measurements are used to calculate the resistance of the groundbed.

449 – 1. Quarterly; annually.
449 – 2. Structure-to-electrolyte potential.
449 – 3. To determine the level of protection and trend of changes in protection.
449 – 4. To check lead continuity, anode condition, and location.
449 – 5. Over the anode.
449 – 6. At the same time structure-to-electrolyte measurements are taken (annually).

449 – 7. Monthly.
449 – 8. The point of maximum potential and three points of minimum potential.
449 – 9. In Section 9 of AF Form 491.
449 – 10. Annually.

450 – 1. −0.85 volt.
450 – 2. Partial protection and may indicate that the leads to one or more anodes are broken, or the anodes are used up.
450 – 3. There is a leak on the structure.
450 – 4. Conduct coating conductance tests and/or Pearson type over-the-ground holiday detector tests. To fix the fault, excavate the line and patch the coating or install additional anodes.
450 – 5. Follow the flow of electricity through the unit.
450 – 6. Turn off the rectifier by throwing the AC circuit breaker and the outside disconnect switch.
450 – 7. The stacks may be defective and should be checked for opens or shorts.
450 – 8. Gas blockage or dry soil; or the anodes may need to be replaced.
450 – 9. Blown fuses, loose terminals, lightning damage, faulty meters, and open circuit breakers.
450 – 10. Check for shorts or overloads and repair damaged components.

CHAPTER 5

451 – 1. T.
451 – 2. T.
451 – 3. F. The signal may be audible, visual, or a combination.
451 – 4. F. They may be coded or uncoded.
451 – 5. T.
451 – 6. F. They are to notify the occupants to evacuate.
451 – 7. T.

452 – 1. Power source, pull station, circuit conductors, and bells.
452 – 2. Closing a switch, completing a current path through the bell circuit.
452 – 3. To warn personnel when operating capability is lost.
452 – 4. Batteries.
452 – 5. Simulates an alarm activation.
452 – 6. Varying the current flow through a network of circuits.
452 – 7. Switch.
452 – 8. The contacts open.

453 – 1. The major command.
453 – 2. No. 14 AWG.
453 – 3. Conduit; raceway.
453 – 4. Line.
453 – 5. 4½.
453 – 6. Recess.
453 – 7. Maintenance; troubleshooting.
453 – 8. AFR 92–1.
453 – 9. Wiring and equipment schematic diagrams, as-built drawings, manufacturers' technical data, and system revision information.
453 – 10. Visual; operational.
453 – 11. At the termination points.
453 – 12. Break the circuit electrically in half.
453 – 13. The same type as removed.

454 – 1. To give the earliest possible notice of an attempted intrusion.
454 – 2. Control unit and its sensor components, and the monitor and display equipment.
454 – 3. Within the protected structure.
454 – 4. Battery power will automatically switch over.
454 – 5. Secure, Access, Test/Reset.
454 – 6. Motion sensor.
454 – 7. The status of the monitor cabinet power.
454 – 8. Status monitor module.

455 – 1. 20 VDC.
455 – 2. A rise in ohmic valve in the circuit.
455 – 3. It produces metal shavings.
455 – 4. Covers will be secured with a tamper switch, by tack welding, brazing, or epoxy filling, or provided with twist-off screws.
455 – 5. Power conductors NO. 14 AWG; low voltage conductors NO. 22 AWG.
455 – 6. The diagram should show the complete system, be marked Confidental, and placed in an appropriate container.
455 – 7. T.O. series 3159–4.

456 – 1. For their own protection.
456 – 2. T.O. series 315–4.
456 – 3. To indicate which group of sensors processed an alarm condition.
456 – 4. An alarm reading of 20 VDC; no alarm reading is 0 VDC.
456 – 5. Minimum of 19 VDC to maximum of 21 VDC.
456 – 6. Replacement.
456 – 7. To bring the system back on line as soon as possible.
456 – 8. Tag your conductors.

CHAPTER 6

457 – 1. X.
457 – 2.
457 – 3. X.
457 – 4.
457 – 5.
457 – 6. X.

458 – 1. Medical; dental.
458 – 2. Mental; physical.
458 – 3. Broken in.
458 – 4. Dry footwear; massage.
458 – 5. Salt.
458 – 6. Exercise.
458 – 7. Training.

459 – 1. Deserts are more often made up of rock and scrub vegetation.
459 – 2. X.
459 – 3. X.
459 – 4. Shoes should be thick and sturdy to protect from rocks and thorns.
459 – 5. X.
459 – 6. X.
459 – 7. X.
459 – 8. X.
459 – 9. Footwear should be made up of layers of clothing and should not bind or restrict circulation.
459 – 10. Blood feeding insects are a problem in artic areas in the summer only.
459 – 11. X.
459 – 12. Trench foot is more of a problem in arctic summers than winters.

460 – 1. An "X" should be placed by b, d, e, f, and g.

461 – 1. True.
461 – 2. True.
461 – 3. True.
461 – 4. True.
461 – 5. False.

CHAPTER 7

462 – 1. An "X" should be placed by a and d.
462 – 2. An "X" should be placed by c.

463 – 1. a. Knob and tube: A positive and negative conductor bus run in an overhead space with the conductors supported on porcelain split insulators.
b. Twisted wire and cleats: Adaptation of knob and tube with a twisted pair of wires separated for bus taps by ceramic cleats.
c. Ground return, single wire: The earth is used as the neutral.
463 – 2. a. Twisted wire and cleats.
b. Knob and tube.
c. Ground return, single wire.
464 – 1. Most foreign systems have not been installed in accordance with the NEC. This is attributed largely to material shortages.
464 – 2. Converted; modified; inefficiently.
464 – 3. The electrician or unit commander may use foreign equipment which may be difficult to obtain or they may modify standard U.S. equipment to use with the foreign system.

464 – 4. Both lamp and ballast life will be shortened.
464 – 5. Obtain a frequency changer to use with receiving transmitting equipment. The only time this equipment should be used without a changer is in an emergency as it will not operate satisfactorily either below or above the rated frequency.
464 – 6. A special joint compound must be applied to all connections or joints.

465 – 1. A walkaround inspection for the general condition of the truck.
465 – 2. Leaks of oil, fuel, hydraulic fluid, water, antifreeze, or brake fluid.
465 – 3. Cuts, wear, direction of rotation, and proper inflation.
465 – 4. Familiarize yourself with the location of the gauges, adjust the seat and mirror, and fasten the seat belt. Place the transmission in neutral with the clutch disengaged, set the brake, and turn the ignition to start.
465 – 5. The oil pressure gauge or light.
465 – 6. To allow the transmission fluid to circulate.
465 – 7. To remove condensation.
465 – 8. ¾ tank; to reduce condensation and to have enough in case of an emergency.
465 – 9. Park or reverse.
465 – 10. Hydraulics.
465 – 11. Lay the forks flat on the ground.

466 – 1. Flats on inside duals can be changed by using a 2-inch block under the inflated tire to raise the vehicle. Block the axle and dig the dirt out from the blocked tire.
466 – 2. First, try digging the soil from in front of the wheel with a shovel, mattock, axe, or pick. If that proves unsuccessful, obtain a log or piece of heavy timber long enough to reach across the hole in front of the wheel. Fasten the log to the wheel with a chain. Apply power to the wheel; when the wheel pulls out of the hole have someone fill the hole with rock or other suitable material.
466 – 3. Back up the vehicle until the A-frame is upright.
466 – 4. Use of a properly fastened towbar; or, if not available tie front bumper of towed vehicle tightly to the rear of the towing vehicle.
466 – 5. Skid; timber.
466 – 6. (1) Single line straight pull. (2) The one using both the spreader bar and the snatch block.
466 – 7. The shear pin will break, or the brake lining will be needlessly worn.
466 – 8. Fasten a rope between the duals on one side of the truck and those on the opposite side. Fasten the ends to an anchor. When power is applied to the wheels, the rope winds up between the duals to exert a pull.
466 – 9. Use roads where your vehicle is concealed by natural vegetation; avoid dusty roads.
466 – 10. To prevent changes or markings, such as tire tracks, that would be readily apparent to the enemy.

467 – 1.
- a. Hammer the broken line flat between the break and the line to the other wheel; or on a broken hose fold the end over and twist a wire around it tightly.
- b. Plug the puncture with soap or a stick.
- c. Loosen the generator and tie a small rope or a strand from a larger rope around the pulleys. Sometimes the ends of the broken belt can be wired together.
- d. If it occurs shortly after a stop, pour cold water over the fuel pump and fuel line; if water is not available, open the hood and let the engine cool. If it occurs while the vehicle is in operation, use a wet rag and wrap it around the fuel pump and sediment bowl.
- e. Break the line and install a piece of hose from the windshield wiper or air horn over the two ends; an alternate method is to wrap the broken line tightly with plastic tape or other nonporous material, secured with closely wrapped wire or string.
- f. Wipe off carefully all wiring and distributor, including inside cap and rotor.

467 – 2. It may cause sparks or short out the good battery.
467 – 3. To prevent sparks from igniting hydrogen gas from the batteries.
467 – 4. In the reverse order from the way originally connected.

468 – 1. On a sloping surface, locate the work to avoid extending the booms to their maximum reach on the downhill side.
468 – 2. The lower boom will rise.
468 – 3. (1) Set truck's parking brake before operating boom.
(2) Set outriggers.
(3) Use safety belts.
(4) Close outrigger lock valves before operating boom.
(5) Operate controls slowly and smoothly.
468 – 4. Qualified operators only.
468 – 5. At the main hydraulic control valve near the base of the lower boom.

469 – 1. A boom, a winch, and a capstan.
469 – 2. A power takeoff from the line truck engine supplies the power.
469 – 3. It is equipped with an automatic brake to prevent turning under load except when the truck engine turns it.
469 – 4. 30.
469 – 5. It is used for raising loads.

470 – 1.
- a. Close column march.
  Advantages: Full traffic capacity of the road is used; better communication; fewer guides, escorts, and markers needed. Disadvantages: No protection from observation and attack; scheduling problems; greater driver fatigue; limits use of highway to local traffic.
- b. Open column march.
  Advantages: Offers more protection from attack and observation; allows greater speed; reduces driver fatigue. Disadvantages: Problems in communication; maintaining space between elements difficult for drivers; smaller traffic volume.
- c. Infiltration.
  Advantages: Best defense against hostile observation and attack; higher speeds; each individual vehicle has more freedom. Disadvantages: Longer time to complete; hard to regulate; more detailed briefing required; halts more difficult to plan.

470 – 2. Head, main body, and trail.
470 – 3. The pace setter (usually the same as the slowest vehicle).
470 – 4. A detached party operates apart from the march and performs special duties in advance of or following the convoy.
470 – 5. They provide for periods of rest, personal comfort, messing, refueling, maintenance and inspection of equipment, and to allow other traffic to pass.
470 – 6. They should be scheduled to allow 10 minutes rest after each 110 minutes of running time.
470 – 7. (1) The comfort of personnel and (2) servicing facilities for vehicles.

470 – 1. The amount and type of cargo that is to be moved.
471 – 2. It is used to gather information concerning the route and the adjacent areas for planning the move.
470 – 3. Number and type vehicles needed.
471 – 4. Maps; forecasters. Fuel (or repairs, rations, water); points (or bottlenecks).

472 – 1. 60 miles.
472 – 2. 1100 hours.
472 – 3. 1130 hours.
472 – 4. 7 miles.
472 – 5. Jackson Heights.

473 – 1. Communications within a convoy can be handled with sign messages, written messages, two way radios, sounds, and signals (such as hand and arm signals).
473 – 2. Messenger or pick-up from guide along route.
473 – 3. Signs posted on roadway.

474 – 1. The American Trucking Association, Inc.
474 – 2. State, local, and military officials, and the Director of Transportation, Headquarters USAF.
474 – 3. The base transportation officer.
474 – 4. The security officer.
474 – 5. DD Forms 1265 and 1266.

1985-631-028/20701 AUGAFS,AL(860916)1300

S T O P - 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

54250 03 21
INSTALLATION AND MAINTENANCE OF
MOTORS, CONTROLS, AND SPECIAL EQUIPMENT

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet .
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you have to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If mandatorily enrolled student, process questions or comments through your unit trainer or OJT supervisor. If voluntarily enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the Learning Objective Number where the answer to that item can be located. When answering the items on the VRE, refer to the Learning Objectives indicated by these Numbers. The VRE results will be sent to you on a postcard which will list the actual VRE items you missed. Go to the VRE booklet and locate the Learning Objective Numbers for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

## MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the best answer to each question.

1. (400) Which of the following is not a part of a DC motor?

   a. An armature.
   b. A stator.
   c. A brush assembly.
   d. End bells.

2. (401) The device that reverses the current flow through the armature windings is the

   a. end bells.
   b. brush assembly.
   c. field coils.
   d. commutator.

3. (401) Which of the following is distinguished by the speed changes that vary rapidly with the load?

   a. The series motor.
   b. The shunt motor.
   c. The compound motor.
   d. The universal motor.

4. (402) What component of a three phase motor is connected to the load?

   a. The end bells.
   b. The rotor.
   c. The stator.
   d. The armature.

5. (403) The magnetic field of a three phase motor rotor is caused by the

   a. current flow in the rotor.
   b. resistance in the squirrel cage.
   c. impedance of the stator.
   d. voltage in the end bells.

6. (403) Which of the following would have the highest RPM if connected to the same power supply?

   a. 4 pole motor.
   b. 6 pole motor.
   c. 12 pole motor.
   d. 24 pole motor.

7. (404) The internal connections of a three phase motor are

   a. either series or parallel.
   b. always in series with the supply.
   c. either wye or delta connections.
   d. always in parallel with the load.

8. (405) The motor that requires some starting means is

a. the single phase AC motor.
b. the three phase AC motor.
c. the DC shunt motor.
d. the universal motor.

9. (405) A centrifugal switch is used in a single phase motor

a. to engage the power leads.
b. to disconnect the start windings.
c. to engage the run windings.
d. to disconnect the capacitor.

10. (406) A simple repulsion motor will have the operating characteristics of a high starting torque and

a. low current draw.
b. a steady speed control.
c. higher RPM with heavy loads.
d. all of the above characteristics.

11. (407) A single phase motor with the external leads numbered T1, T2, T3, and T4 would be

a. a single-voltage, nonreversible type.
b. a single-voltage, reversible type.
c. a dual-voltage, nonreversible type.
d. a dual-voltage, reversible type.

12. (408) There are how many basic types of across-the-line motor controls?

a. 5.
b. 4.
c. 3.
d. 2.

13. (409) In most magnetic across-the-line motor controllers, contact chatter is reduced by using

a. an arc chute.
b. plastic bumpers.
c. shading rings.
d. mechanical latches.

14. (409) The basic types of overload relays are

a. mechanical and magnetic.
b. under voltage and over current.
c. single and three phase.
d. thermal and magnetic.

15. (410) When a switch in the circuit that supplies power for the electromagnetic coil is opened, what kind of force causes the contacts to be pulled apart?

a. Magnetic.
b. Spring tension.
c. Hydraulic.
d. Thermal.

16. (410) Which of the following devices is temperature sensitive and is widely used in heating and cooling systems to control the system?

a. A float switch.
b. A pressure switch.
c. A thermostat.
d. A photoelectric cell.

17. (411) What type of bearing should be used in a motor that will be mounted vertically?

a. Oillite sleeve.
b. Bronze sleeve.
c. Ball or roller.
d. Phenolic and brass sleeve.

18. (412) When cleaning a motor with compressed air, what is the maximum air pressure that should be used?

a. 15 psi.
b. 25 psi.
c. 35 psi.
d. 50 psi.

19. (413) If a motor that has been operating normally suddenly stops, you should suspect

a. improper connections.
b. an overvoltage.
c. an electrical overload.
d. worn brushes.

20. (414) In a three phase motor if a squirrel-cage rotor is open, the motor will

a. slow down under load.
b. accelerate under load.
c. have a high starting torque.
d. stop.

21. (415) Each of the following are common malfunctions in electrical motors <u>except</u>

a. overspeeding.
b. stopping.
c. running hot.
d. failing to start.

22. (416) There are how many types of hazardous locations?

a. 5.
b. 4.
c. 3.
d. 2.

23. (417) Electrical equipment used in Class I locations must be

a. spark-proof.
b. dust-proof.
c. water-proof.
d. explosion-proof.

24. (418) Which of the following wiring is required in a Class I hazardous location?

a. A knob-and-tube.
b. A mineral-insulated cable.
c. A non-metallic sheathed cable.
d. EMT conduit protected circuits.

25. (418) To prevent explosive materials from passing from one part of an explosion-proof conduit system to another, you should use

a. an epoxy.
b. rubber seals.
c. cork seals.
d. a sealing compound.

26. (419) Before servicing or disassembling electrical equipment, you should always

a. deenergize the circuits.
b. check the manufacturer's manual.
c. put on rubber protective equipment.
d. disassemble the enclosures.

27. (420) When working in a class I hazardous location all the equipment listed below must be used <u>except</u> for

a. class I flashlights.
b. SO flexible hand service cord.
c. battery powered test equipment.
d. non-sparking hand tools.

28. (421) A transformer will pass electrical energy from one circuit to another with almost no change of

a. voltage.
b. current.
c. resistance.
d. frequency.

29. (422) The coil insulation and bushing of a transformer will determine

a. the current.
b. the voltage.
c. the wattage.
d. the power output.

30. (423) What percentage of a current rating must the over-current device of a 600 volt transformer have?

a. 80%.
b. 95%.
c. 125%.
d. 150%.

31. (423) A three phase transformer that supplies power only should be connected

a. delta-wye.
b. wye-delta.
c. wye-wye.
d. delta-delta.

32. (424) If a voltmeter is connected across the terminal transformer output and the resulting reading is zero, this reading would indicate

a. an open secondary coil.
b. an open primary coil.
c. an open in the transformer but not which coil.
d. an open power supply.

33. (424) A partial short across a transformer winding would be indicated by

a. a loss of voltage.
b. a drop in voltage.
c. an increase in current.
d. an increase in power.

34. (425) Two basic types of voltage regulators are

a. series and parallel.
b. series and shunt.
c. wye and delta.
d. open and closed.

35. (425) The voltage regulator that will handle very large amounts of power is the

a. magnetic amplifier.
b. vaccuum tube regulator.
c. semi-connector regulator.
d. delta wound regulator.

36. (426) The regulating ability of a regulated power supply is generally given as

a. a percent of change.
b. no load to full load.
c. a current flow.
d. a percentage of voltage change from no load to full load.

37. (427) The two basic types of batteries are

a. AC and DC.
b. primary and secondary cells.
c. wye and delta.
d. single phase and three phase.

38. (428) Batteries connected in series

a. will provide a higher voltage.
b. will provide more current.
c. cannot be recharged.
d. will provide more power than batteries connected in parallel.

39. (429) A device most often used to change AC to DC is

a. a generator.
b. an alternator.
c. a transformer.
d. a rectifier.

40. (429) A single phase, full wave dry disc rectifier will have how many connection terminals?

a. 3.
b. 4.
c. 5.
d. 6.

41. (430) An excessive current flow through a dry disc rectifier would be indicated by

a. a low voltage.
b. distorted wave forms.
c. heat.
d. magnetic fields.

42. (431) If a battery is suspected of causing trouble, your first check should be with a

a. a voltmeter.
b. an ammeter.
c. a multimeter.
d. a hydrometer.

43. (432) The normal lighting device used with emergency lights is

a. a 220 watt flourescent tube.
b. a 40 watt, 120 volt incondescent bulb.
c. a 25 watt, 6 volt sealed-beam lamp.
d. a 250 watt, 120 volt HID bulb.

44. (433) How long must the power supply to an emergency light be able to supply voltage in an emergency?

a. Indefinitely.
b. 24 hours.
c. 12 hours.
d. 1 1/2 hours.

45. (434) A total discharge of emergency light batteries and recharge should be performed

a. yearly.
b. every six months.
c. monthly.
d. weekly.

46. (435) The most common automatic temperature control for cooking appliances is the

a. bimetallic strip.
b. helix.
c. hydraulic.
d. diaphragm.

47. (436) The two basic types of heating elements used by the Air Force for appliances are

a. the rod coil and ribbon.
b. the open and enclosed.
c. the suspended and spiral.
d. the surface and immersed.

48. (436) A type of heating element that <u>cannot</u> be economically repaired is the

a. open coil.
b. suspended coil.
c. ribbon.
d. enclosed.

49. (437) There are how many basic types of space heaters?

a. 2.
b. 3.
c. 4.
d. 5.

50. (438) In how many ways may kitchen equipment be connected to a power source?

a. 2.
b. 3.
c. 4.
d. 5.

51. (439) The <u>first</u> step in troubleshooting an appliance should be

a. to check the power.
b. to perform a visual inspection.
c. to perform an operational check.
d. to disassemble the appliance.

52. (439) When electrical power is <u>not</u> getting to the range at all, you should look for

a. an "open" in the main circuit.
b. a blown "K" fuse.
c. frozen contacts.
d. a defective blower.

53. (440) If you are checking a heating element with an ohmmeter and the ohmmeter reads "0", this would indicate that the element is

a. good.
b. open.
c. shorted.
d. grounded.

54. (441) Corrosion is what type of a process?

a. A chemical or electrochemical reaction.
b. An electro-acid reaction.
c. An electromagnetic reaction.
d. An acid reaction.

55. (442) There are how many basic forms of normal corrosion?

a. 2.
b. 3.
c. 4.
d. 5.

56. (442) Where would stray current corrosion cause the greatest damage?

a. Where it enters the pipe.
b. At a midpoint between entry and exit.
c. At the bottom side of the pipe.
d. Where currents leave the pipeline.

57. (443) When the anodic current flow is zero, corrosion will

a. be at its greatest.
b. cease.
c. continue at a steady rate.
d. increase.

58. (444) The cathodic protection system that requires the most maintenance is the

a. magnesium to iron galvanic system.
b. aluminum to steel galvianic system.
c. impressed current system.
d. graphite to iron galvanic system.

59. (445) The basic guidance for completing maintenance action sheets will be found in

a. AFP 66-1.
b. AFR 85-1.
c. TO 35Y-19.
d. the naticnal electric code.

60. (445) A good source of information for monthly readings on water storage tanks is

a. AFP 661.
b. AFM 85-5.
c. TO 35Y-19.
d. AFM 127-101.

61. (446) To protect a steel or cast iron structure, what should the voltage reading be between the structure and a staturated copper-copper sulphate half-cell contacting the electrolyte?

a. +85 volts.
b. +8.5 volts.
c. -0.85 volts.
d. -8.5 volts.

62. (447) What meter should you use when making structure-to-electrolyte measurement?

a. A megohmmeter.
b. An ammeter.
c. A high-resistance voltmeter.
d. A potentionmeter.

63. (448) The ability of a material to stop the flow of electricity is known as

a. ohms.
b. resistance.
c. impedance.
d. resistivity.

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64. (449) After the initial level of cathodic protection of a galvanic anode system is established, how often should the system be checked during the first year?

a. Weekly.
b. Monthl-.
c. Quarterly.
d. Semiannually.

65. (450) A reading of -0.50 volts on a galvanic anode would indicate

a. over protection.
b. a good reading.
c. no protection.
d. under protection.

66. (451) Which fire alarm system provides an audible, visual or a combination of signals, but does not make a permanent record?

a. Coded.
b. Uncoded.
c. Supervised.
d. Unsupervised.

67. (452) What basic device governs all automatic fire alarm detectors?

a. A switch.
b. A resistor.
c. A relay.
d. An electromagnet.

68. (452) On what principle does the closed type fire alarm detector operate?

a. Trouble.
b. Test.
c. Supervision.
d. Manual.

69. (454) What is the primary notification equipment of the JSIIDS?

a. A monitor cabinet.
b. A control cabinet.
c. Sensor components.
d. Operating modes.

70. (455) What is the basic operating voltage and resistance of a JSIIDS under a no alarm condition?

a. A 20 volt AC circuit and less than 2 thousand ohms resistance.
b. A 20 volt DC circuit and less than 2 thousand ohms resistance.
c. A 10 volt DC circuit and more than 100 thousand ohms resistance.
d. A 10 volt AC circuit and more than 100 thousand ohms resistance.

71. (456) What component inside the JSIIDS control unit is designed for fast and easy troubleshooting?

a. A status processor.
b. A monitor module.
c. An alarm module.
d. A display equipment.

72. (457) The site selection for latrines will be

a. made prior to selecting camp sites.
b. the responsibility of the medical or veterinary section.
c. down wind from the tent area.
d. located at the highest nearby area.

73. (458) A person's physical capabilities are generally

a. far greater than the person believes.
b. less than the person believes.
c. about the amount the person believes.
d. variable from day to day.

74. (458) "Trench foot" is caused

a. by hot weather.
b. by the feet being wet and cold for extreme periods.
c. by hot, dry conditions that cause feet to sweat.
d. by cold, dry conditions.

75. (459) What type of problem is caused by desert rain?

a. High humidity.
b. Insects.
c. Flash flooding.
d. Rapid changes in temperature.

76. (460) When patrolling in hostile areas, you should avoid

a. ditches.
b. grass areas.
c. brush and trees.
d. ridge lines.

77. (461) Whenever possible in transporting a victim, you should use

a. the fireman's carry.
b. two people.
c. a litter.
d. the pistol belt carry.

78. (462) What is used to seal moisture out of a weather head made from a service entrance cable?

a. Plastic electrician's tape.
b. Fiction tape.
c. Varnish.
d. A cap.

79. (463) What type of a branch circuit can be installed in an expedient method by placing both the positive and negative conductors on porcelain split insulators?

a. A double wire.
b. A ground return.
c. A knob and tube.
d. A twisted wire and cleats.

80. (463) What wiring component used in contingency operations could, if misused, dangerously overload a circuit?

a. Cleats.
b. Split insulators.
c. Duplex outlets.
d. Drop sockets.

81. (464) What frequency is commonly found in many foreign countries?

a. 50 cycle.
b. 60 cycle.
c. 80 cycle.
d. 100 cycle.

82. (464) What percent lighting efficiency is lost for a 115V incandescent lamp operating on 95V?

a. 10 percent.
b. 25 percent.
c. 40 percent.
d. 50 percent.

83. (465) A tool you should have with you when making a walk-around inspection of a military vehicle is

a. a screwdriver.
b. a voltmeter.
c. a hydrometer.
d. an air pressure gauge.

84. (466) If a wrecker is not available, the preferred method of towing a vehicle is with a

a. chain.
b. rope.
c. cable.
d. towbar.

85. (466) What is incorporated into a winch to prevent overload damage?

a. A shear pin.
b. A safety brake.
c. A disk clutch.
d. A load link.

86. (467) If you have lost hydraulic fluid in a brake line and repaired the break, you can then fill the master cylinder with

a. gasoline.
b. engine oil.
c. water.
d. soap.

87. (467) What can be used to dry a wet ignition system?

a. Gasoline.
b. Engine oil.
c. Sand.
d. A clean dry cloth.

88. (468) At the job site, the bucket truck should be positioned so that the working area is

a. directly over the truck.
b. within reach of the boom.
c. always in front of the truck.
d. always to the right side of the operator.

89. (469) Power is supplied to the line truck winch

a. from the truck engine through the power take off.
b. from the engine through the back transmission.
c. through a direct drive from the engine.
d. through the transfer case.

90. (470) There are how many basic convoy types?

a. 2.
b. 3.
c. 4.
d. 5.

91. (471) Which of the following should you coordinate with before putting a convoy on the road in the US?

a. The military police.
b. The Railroad Commission.
c. The civil traffic authorities.
d. The United States Highway Commission.

92. (472) A time-distance diagram used for planning and controlling a convoy over a given route is called a

a. planning sheet.
b. convoy chart.
c. march graph.
d. staking sheet.

93. (473) Written messages should be

a. posted on the right shoulder of the road.
b. posted on the left shoulder of the road.
c. passed from vehicle to vehicle.
d. delivered by messengers only.

94. (474) Vehicles carrying explosives must be marked with placards on which the letters are

a. in red.
b. at least 6 inches high.
c. reflectorized.
d. in international orange and 2 inches high.

END OF EXERCISE

<u>ATC/ECI SURVEY</u>

The remaining questions (125-135) are not part of the Volume Review Exercise (VRE). These questions are a voluntary ATC/ECI survey. Using a number 2 pencil, indicate what you consider to be the appropriate response to each survey question on your answer sheet (ECI Form 35), beginning with answer number 125. Do not respond to questions that

do not apply to you. Your cooperation in completing this survey is greatly appreciated by ATC and ECI. (AUSCN 100)

PRIVACY ACT STATEMENT

A. Authority: 5 U.S.C. 301, Departmental Regulations

B. Principal Purpose: To gather preliminary data evaluating the ATC/ECI Career Development Course (CDC) Program.

C. Routine Uses: Determine the requirement for comprehensive evaluations in support of CDC program improvement.

D. Whether Disclosure is Mandatory or Voluntary: Participation in this survey is entirely voluntary.

E. Effect on the Individual of not Providing Information: No adverse action will be taken against any individual who elects not to participate in any or all parts of this survey.

QUESTIONS:

125. If you have contacted ECI for any reason during your enrollment, how would you describe the service provided to you?

a. Excellent.
b. Satisfactory.
c. Unsatisfactory.
d. Did not contact ECI.

126. My ECI course materials were received within a reasonable period of time.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

127. The condition of the course materials I received from ECI was:

a. A complete set of well-packaged materials.
b. An incomplete set of well-packaged materials.
c. A complete set of poorly packaged materials.
d. An incomplete set of poorly packaged materials.

128. The reading level of the material in the course was too difficult for me.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

129. The technical material in the course was too difficult for me at my present level of training.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

130. The illustrations in the course helped clarify the information for me.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

131. Approximately how much information in the course provides general information about your AFSC?

a. Between 80 and 99%.
b. Between 60 and 79%.
c. Between 40 and 59%.
d. Between 20 and 39%.

132. Approximately how much information in this course was current?

a. Between 80 and 99%.
b. Between 60 and 79%.
c. Between 40 and 59%.
d. Between 20 and 39%.

133. The format of the text (objective followed by narrative and exercises) helped me study.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

134. The volume review exercise(s) helped me review information in the course.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

135. Check the rating which most nearly describes the usefulness of the information in this CDC in your upgrade training program.

a. Excellent.
b. Satisfactory.
c. Marginal.
d. Unsatisfactory.

NOTE: If you know this CDC contains outdated information or does not provide the knowledge that the current specialty training standard requires you to have for upgrade training, contact your OJT advisor and fill out an AF Form 1284, Training Quality Report.

MAIL TO· ECI, GUNTER AFS AL 36118-5643

# STUDENT REQUEST FOR ASSISTANCE

PRIVA Y ACT STATEMENT

AUTHORITY: 10 USC 8012. PRINCIPAL PURPOSE: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package, and used by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's inquiry. Failure to provide all information would result in slower action or inability to provide assistance to the student.

I. CORRECTED OR LATEST ENROLLMENT DATA

| 1. THIS REQUEST CONCERNS COURSE (1-6) | 2. TODAY'S DATE | 3. ENROLLMENT DATE | 4. AUTOVON NUMBER |
|---|---|---|---|
| | | | |

| 5. SOCIAL SECURITY NUMBER (7-15) | 6. GRADE/RANK | 7. NAME (First initial, second initial, last name) |
|---|---|---|
| _ _ _ – _ _ – _ _ _ _ | | (17) – (18) – (19-32) |

| 8. ADDRESS | |
|---|---|
| OJT ENROLLEES--Address of unit training office with zip code. | (33-53) |
| ALL OTHERS--Current mailing address with zip code. | (54-75) |

| 9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE | 10. TEST CONTROL OFFICE ZIP CODE/SHRED (33-39) |
|---|---|
| | |

II. REQUEST FOR MATERIALS, RECORDS, OR SERVICE

| X | Place an 'X' through number in box to left of service requested. | FOR ECI USE ONLY | |
|---|---|---|---|
| 1 | Request address change as indicated in Section I, Block 8. | | |
| 2 | Request Test Control Office change as indicated in Section I, Block 10. | | |
| 3 | Request name change/correction. *(Provide Old or Incorrect data here)* | | |
| 4 | Request Grade/Rank change/correction. | | |
| 5 | Correct SSAN. *(List incorrect SSAN here.) (Correct SSAN should be shown in Section I.)* | | |
| 6 | Extend course completion date. *(Justify in "Remarks")* | | |
| 7 | Request enrollment cancellation. *(Justify in "Remarks")* | 16 G | 33 |
| 8 | Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 10 Originals were: [ ] Not received [ ] Lost [ ] Misused | K | VOL 33-35 GR 36-38 |
| 9 | Send course materials. *(Specify in "Remarks")* [ ] Not received [ ] Lost [ ] Damaged | M | 33-34 35-40 |
| 10 | Course exam not yet received. Final VRE submitted for grading on ____________(date). | N | 33-35 |
| 11 | Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 10 not yet received. Answer sheet(s) submitted ______________(date). | P | VOL 33-35 |
| 12 | Results for CE not yet received. Answer sheet submitted to ECI on ____________(date). | | TC 36-37 38 |
| 13 | Previous inquiry ([ ] ECI Fm 17, [ ] ltr, [ ] msg) sent to ECI on ____________(date). | | DOE 39-45 |
| 14 | Give instructional assistance as requested on reverse. | Q | 33-34 ØØ 38 1 |
| 15 | Other *(Explain fully in "Remarks")* | | MC 39-42 |

REMARKS *(Continue on reverse)*

| | |
|---|---|
| *OJT STUDENTS must have their OJT Administrator certify this record.* | *I certify that the information on this form is accurate and that this request cannot be answered at this station.* |
| *ALL OTHER STUDENTS may certify their own requests.* | SIGNATURE |

ECI FORM DEC 84 17 PREVIOUS EDITION WILL BE USED.

## REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of subject matter should be forwarded directly to preparing agency. For an immediate response to these questions, call or write the course author directly, using the AUTOVON number or address in the preface of each volume. All other inquiries concerning the course should be forwarded to ECI.

**VRE ITEM QUESTIONED:**

COURSE NO ________

VOLUME NO ________

VRE FORM NO ________

VRE ITEM NO ________

ANSWER YOU CHOSE ________
*(Letter)*

HAS VRE ANSWER SHEET BEEN SUBMITTED FOR GRADING?

☐ YES ☐ NO

**REFERENCE**

*(Textual reference for the answer I chose can be found as shown below.)*

IN VOLUME NO ________

ON PAGE NO ________

IN ☐ LEFT ☐ RIGHT COLUMN

LINES ______ THROUGH ______

**MY QUESTION IS:**

**REMARKS**

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. Course workbooks have a Form 17 printed on the last page.

ECI FORM 17, DEC 84 *(Reverse)*

AU GAFS, AL (860790) 1000

54250 00 S01 8406

CHANGE SUPPLEMENT

CDC 54250

# ELECTRICIAN

(AFSC 54250)

IMPORTANT: Make the corrections indicated in this supplement before beginning study of this course. This supplement contains both ''pen-and-ink'' changes and replacement pages. It is perforated and three-hole-punched so that you can tear out the replacement pages and insert them in your volumes. You are not required to post any changes listed in this supplement which correct typographical errors, unless such errors change or otherwise affect the meaning of the material.

AIR UNIVERSITY

Extension Course Institute
Air University

646

## CHANGES FOR THE TEXT: VOLUME 1

### Pen-and-Ink Changes:

In the following locations, change "AF Form 601b" to "AF Form 601."

| *Page-Col* | *Line* |
|---|---|
| 54R | 3 |
| | 26 |
| | 11 fr bot |
| | 12 fr bot |
| | 15 fr bot |
| 56L | 9 |

| *Page-Col* | *Subject* | *Line(s)* | *Correction* |
|---|---|---|---|
| 6L | | 27–28 | Delete "(UTC4F9CA)." |
| 6R | | 4 | After "Both" change "CF-2" to "CF-1." |
| 21R | 017 - 1 | 3 | Change "1" to "A." |
| 25R | | 15 | Change "AFR" to "AFP." |
| 29R | | 5 | Change "0)en1-44" to "TO 0–1–44." |
| 34L | 020 - 3 | *Col B* | Add "AFR 0–14" after "i." |
| 44L | | 14 fr bot | Before "Identify" insert "031." |
| 84L | 055 | 3,6 | Number exercises "3" and "4," respectively. |
| 85L-110L | | | Delete objectives 057–076, including all exercises and figures 3-7 through 3-15. |
| 144L–145R | | | Delete answers 057-1 through 076-6. |
| 146R | | 3 fr bot | Delete "h'27u'." |

### Page Changes:

| *Remove Pages* | *Insert Pages* |
|---|---|
| 7–12 | 7–12 |
| 39–40 | 39–40 |
| 45–48 | 45–48 |
| 55–56 | 55–56 |
| 127–128 | 127–128 |
| 133–134 | 133–134 |
| 141–142 | 141–142 |
| 145–147 | 145–147 |

9. What is each CF-2 team member personally issued in the way of equipment?

10. What weapons are Prime BEEF teams trained on?

**005. State the function of a RED HORSE Squadron and identify the echelon of deployment from a list of tasks.**

**Function of REDHORSE.** Air Force squadrons with the title "RED HORSE" have the ability to repair major damage that is inflicted on a base. RED HORSE means "Rapid Engineer Deployable Heavy Operations Repair Squadrons Engineer." "RED HORSE" is much easier for you to say. The title explains, to a large extent, the function of the RED HORSE unit.

RED HORSE squadrons provide heavy equipment repair and construction of troop facilities when and where the requirements exceed the base CE's capabilities, and when Army or Navy support is not readily available. These squadrons are formed with trained personnel from all major commands (MAJCOMS). The members are given training to make them proficient in all areas of their skills. This training is necessary to meet the high standards required of persons in RED HORSE squadrons. RED HORSE squadrons are capable of rapid deployment and are responsive to the following situations:

*a*. Worldwide requirements as directed by Headquarters USAF.

*b*. USAF tactical forces deployed in conjunction with war or the likely event of war.

*c*. Establishment of new base facilities or the expansion and upgrading of existing base facilities.

*d*. The repair or replacement of damaged or destroyed facilities in combat zones.

*e*. Meeting recovery requirements for Air Force facilities in case of natural disasters.

*f*. Training exercises, maneuvers, and special projects.

RED HORSE also makes major construction alterations and additions to an existing base, as would be the case when a runway is lengthened, a hangar is built, or aircraft parking ramps and taxiways are constructed.

The RED HORSE squadron can move on to an abandoned air base and restore it to the extent necessary for flying operations. Also, the squadron can move into an area where there has never been a base and build one.

**Deployment.** RED HORSE Squadrons are organized into three deployment echelons:

CES-1, an air-transportable squadron made up of 14 people and can be deployed 12 hours after notification. This squadron performs advanced airfield surveys, site layout, and prepares for future development of a base of operations during contingencies.

CES-2, an air-transportable squadron made up of 81 people and ca be deployed 72 hours after notification. It can perform heavy bomb damage repair, build shelters, perform limited earthwork and light base development (such as installing aircraft arresting systems, expedient airfield matting, and essential utility systems) during the initial phase of contingencies.

CES-3, a surface movement squadron which can deploy in 10 days after notification, and can perform heavy repair, permanent construction, and airfield expansion.

Each echelon ahs its own separately identified personnel and equipment. Deployment to a bare base is done by CES-1 and CES-2, and is augmented by firefighting or crash rescue teams. A bare base is a base which has as a minimum, a runway, taxiway(s), and parking areas that are adequate for the deployed force, and which has a source of water than can be made potable.

**Exercises (005):**

1. How are RED HORSE Squadrons formed?

2. What services do RED HORSE Squadrons perform?

3. From the list of tasks below performed by RED HORSE Squadrons, designate which echelon performs the task by placing CES-1, CES-2, or CES-3 in the space provided.

a. ___ Field surveys.
b. ___ Rapid runway repair.
c. ___ Install high intensity discharge lighting in a new hangar.
d. ___ Extend an existing runway by 1000 ft.
e. ___ Install an aircraft arresting barrier.
f. ___ Make preparations for future development.

## 1-2. Career Progression

The military services long have recognized that people possess different aptitudes, abilities, and interests. The present airman classification system was adopted shortly after the Air Force became a separate branch of service. It has remained basically unchanged since. The system uses a testing program to identify each airman's aptitude and abilities so that he or she can be assigned to a suitable career field. This system provides a systematic method by which the Air Force insures that each job is filled by well-qualified people. It also affords each person an opportunity to advance within their chosen field according to their abilities. The purpose of the classification system is to identify the duties and tasks to be done in each job and to identify the individuals who have or can develop the abilities to perform the job.

Jobs in the Air Force are classified into career fields. All similar or related jobs are grouped together to form a career field. At present, there are 47 career fields in which airmen can be assigned. Furthermore, each career field is

subdivided into individual jobs or specialties. Each subdivision of a career field is called a career field ladder.

To become better acquainted with your career field, you need specific information. The following objectives provide this information.

**006. Identify AFSC, activities, and responsibilities associated with the steps in an airman mechanical/electrical career ladder.**

**Airman Mechanical/Electrical Career Field Chart.** The chart is a graphic presentation of the 54 career field and is shown in figure 1-2. As you can see, the 54 career field is made up of a number of Air Force specialties. Your specialty, as you well know, is electrician, AFSC 542X0. By observing the chart, you can see just how you fit into the picture. If you are a 3-level electrician, notice that your present position is Apprentice Electrician, AFSC 54230. It is shown just below the position you are working, AFSC 54250. There are pay grades for each skill level. For example, the pay grade for an electrician is E3, E4, or E5.

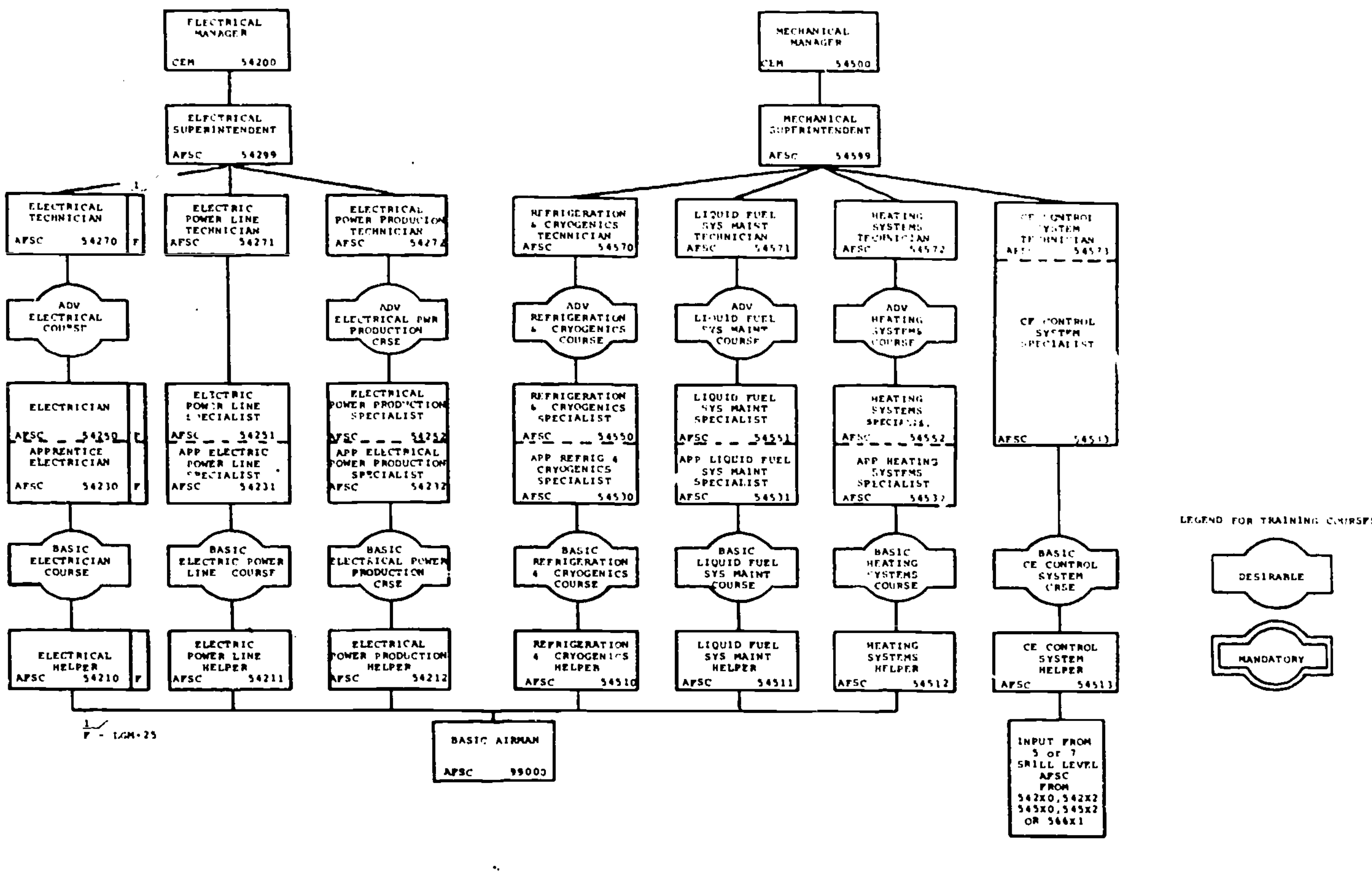


Figure 1-2. Mechanical/electrical career field chart.

The electrical superintendent, AFSC 54299, above the three electrical specialties, is in charge of the three specialties. The three electrical specialties are electrician, power lineman, and power production. The three electrical specialties feed into the superintendent position. The 54 career field includes other specialties, as shown in the chart. Often you will work closely with people from these shops. A cooperative attitude on your part, as well as the other people, will help to get CE jobs done better and faster.

The electrical manager, AFSC 54200, the next position above the electrical superintendent, is an E9, Chief Master Sergeant. This position is known as the Chief Enlisted Manager (CEM). Only a Chief can hold this position. This person has had extensive experience and training, a high managerial ability to plan, direct, coordinat . implement, and control a wide range of work activities in the electrical specialties.

**Exercises (006):**

1. What is the AFSC of each step up the career field ladder from basic airman to manager in your career field? Use figure 1-2.

| TITLE | AFSC |
|---|---|
| a. Basic airman. | |
| b. Electrical helper. | |
| c. Apprentice electrician. | |
| d. Electrician. | |
| e. Electrical technician. | |
| f. Electrical superintendent. | |
| g. Electric manager. | |

2. If you were a 5-level electrician, what is the highest grade you can hold?

3. Your electrical superintendent is from one of what three specialties?

4. What are the electrical manager's main responsibilities?

**007. Select the duties and responsibilities that belong to the specialist level electrician.**

**Duties and Responsibilities of an Electrician.** You must know what your duties and responsibilities are if you are to do your job well. Ability is important and needed, but if you do not know what the job requires, you have trouble in making full use of your abilities. Your duties and responsibilities are found in AFR 39-1, *Airman Classification Regulation*. Your specialty description, AFSC 54250, along with the Electrical Technician, AFSC 54270, and Electrical Superintendent AFSC 54299 has been reproduced here for your convenience and study. Refer to figure 1-3, 1-4, and 1-5.

In figure 1-3, you can see the specialty description you are studying and working toward. Note that it is broken down into four main sections. These are (1) specialty summary, (2) duties and responsibilities, (3) specialty qualifications, and (4) specialty data. Each of these sections has information of value but the most important to you are the "duties and responsibilities" and "specialty qualification." You can see from your specialty description that you do quite a lot of maintenance and repair work and a little supervision. You are expected to perform maintenance work and as you gain in experience and knowledge you will be put in charge of work crews. As you progress up your ladder, you will be doing more supervisory type work. The added supervisory requirements separate the specialist from the apprentice and forms the basis for advancement to the technician position. Study the three specialty descriptions for your career field in this text and know the differences in their requirements. Use the knowledge you have gained here to help you progress in your specialty.

**Exercises (007):**

1. Place an "X" in the space provided beside the duties performed by a specialist level electrician.

____ a. Connects and utilizes test equipment and meters for locating malfunctions.
____ b. Cuts, threads, and bends conduit.
____ c. Solves complex installation and repair problems by studying wiring diagrams.
____ d. Pulls conductors into conduits and raceways.
____ e. Directs electrical maintenance activities.
____ f. Determines procedures for maintenance and modifications of installed equipment.
____ g. Cleans, repairs, and replaces armature and field windings.
____ h. Replaces defective ballasts.
____ i. Reviews repairs to insure compliance with National Electric Code.
____ j. Develops organizational structure to define lines of authority.

## 1-3. Communications Security (COMSEC)

Like safety, security is a topic that applies to each of us all the time. The word "security," of course, refers to the protection of Air Force information and materials. This protection is designed to provide for the Air Force the freedom and secrecy of actions needed to do our part in the national defense.

The fact that you don't handle items marked "classified" doesn't mean you are exempt from taking part in the security program. In fact, those who seldom work in, or with, a security atmosphere, may well be the most vulnerable to another nation's collection of facts related to Air Force operations.

The United States must protect against hostile, destructive, or subversive action. To do this, certain official information affecting the national security must be

AFSC 54250*
Semiskilled AFSC 54230*
Helper AFSC 54210*

## AIRMAN AIR FORCE SPECIALTY

## ELECTRICIAN

### 1. SPECIALTY SUMMARY

Installs, maintains, troubleshoots, repairs and modifies low voltage electrical devices and systems associated with interior feeder and branch circuits, and their overcurrent protection. *Related DOD Occupational Subgroup:* 721.

### 2. DUTIES AND RESPONSIBILITIES

a. *Installs, services, modifies, and repairs electrical equipment and systems.* Inspects, troubleshoots, services, assembles, installs, connects, repairs, adjusts, and tests low voltage interior electrical distribution, control, and utilization equipment and systems. Examines electrical equipment and systems for damages, corrosion, and operation. Connects and utilizes test equipment and meters, such as voltmeters, ammeters, megohmmeters, and oscillographs for locating equipment, distribution, and motor control systems malfunctions and faults. Cleans and adjusts relay timing mechanism and contacts, rotating machinery brushes, circuit breaker and disconnect contacts, and control sensing mechanisms. Repairs and services isolated de-energized high voltage equipment (rotating machinery, circuit breakers, and associated high voltage interior power systems), although 600 volts is normal dividing line between high and low voltage systems, under direct supervision and guidance. Cuts, threads, and bends conduit. Assembles and replaces conduit, conduit fittings, junction boxes, and supports. Pulls conductors into conduits and raceways. Splices conductors. Installs and connects distribution, generation, and utilization equipment components, such as relays, switches, panel boards, transformers, voltage regulators, battery chargers, motor speed controllers, motors, receptacles, lighting fixtures, heating elements, battery banks, generators, circuit breakers, surge protection, ground systems and lightning arrestors. Installs, tests, and maintains power sources for cathodic protection systems. Uses common hand tools, tubing and conduit benders, hand and motor operated conduit threading machines, soldering irons, and hand drills.

b. *Troubleshoots and repairs electrical and industrial electronic circuits and equipment.* Repairs and replaces defective insulated conductors and grounding systems. Cleans, repairs, and replaces armature and field windings. Refaces commutators and slip rings. Replaces defective lamps, lighting fixtures, ballasts, and starters. Installs, maintains, troubleshoots, and repairs explosion proof lighting and wiring systems. Troubleshoots complex motor control circuits and replaces defective components. Performs testing, installation, and repair tasks such as testing and calibrating electric power systems relays and meters, and installs, repairs, and adjusts electrically operated circuit breakers. Replaces defective components in power rectifiers, photoelectric sensors, and voltage and current regulators.

c. *Supervises electrician personnel.* Assigns work and reviews completed repairs to insure compliance with National Electrical Code, safety codes and instructions, and applicable technical publications. Instructs subordinates in techniques and procedures of installation, inspection, maintenance, and repair of interior distribution systems. Evaluates work performed and keeps immediate supervisor informed on job status.

### 3. SPECIALTY QUALIFICATIONS

a. *Knowledge.* Knowledge of principles of electricity to include computations and measurement of common properties (resistance, inductance, capacitance, electrical potential, and current flow); magnetism, electric circuit analysis, rotating machinery operation and control; industrial electronics (operation and elements of rectifiers, voltage regulators, and photoelectric circuits); transformer operations and connections; lightning and system grounding systems and equipment (lightning arrestors, shielding means, power and utilization equipment grounding schemes); cathodic protection; reading and interpretation of electric schematic and one-line diagrams; safety rules and practices; rescue and resuscitation of electric shock victims; operation of test instruments; and use of hand and power tools used in installation and repair of electric equipment and systems is mandatory. Possession of mandatory knowledge will be determined according to AFR 35-1.





### 3. SPECIALTY QUALIFICATIONS

a. *Knowledge.* Knowledge of principles of electricity to include computation and measurement of common properties (resistance, inductance, capacitance, electric potential, and current flow), magnetism, electric circuit analysis, rotating machinery operation and control, repair, servicing, and installation of high voltage equipment, motor control, circuits, and protective devices (synchronous and induction motor controllers, overcurrent and overvoltage protection), transformer operations and connections, electrical equipment control circuits (servomechanisms, temperature sensing devices, types and functions of relays), lightning and system grounding systems and equipment (lightning arrestors, shielding means, power and utilization equipment grounding schemes), reading and interpretation of electric schematic and one-line diagrams, safety rules and practices, rescue and resuscitation of electric shock victims, operation of test instruments, and use of hand power tools used in the installation and repair of electric equipment and systems is mandatory. Possession of mandatory knowledge will be determined according to AFR 35-1.

b. *Experience.* Qualification as an Electrician is mandatory. In addition, experience in performing or supervising functions such as the installation, maintenance, troubleshooting, and repair of electrical distribution and utilization equipment and systems is mandatory.

c. *Training.*

(1) Completion of prescribed 7-level management course is mandatory.

(2) Completion of an advanced electrician course is desirable.

### 4. *SPECIALTY SHREDOUTS

| *Suffix* | *Portion of AFS to Which Related* |
|---|---|
| F | LGM-25 |

Figure 1-3. Electrician.

BEST COPY AVAILABLE

## AIRMAN AIR FORCE SPECIALTY

## ELECTRICAL TECHNICIAN

### 1. SPECIALTY SUMMARY

Inspects, installs, services, troubleshoots, repairs, plans and modifies low voltage electrical and electronic equipment and systems associated with generation, distribution, utilization, and control systems, and supervises electrical activities. *Related DOD Occupational Subgroup:* 721.

### 2. DUTIES AND RESPONSIBILITIES

a. *Advises on technical problems of installation, modification, and repair of electrical real property installed equipment and systems.* Solves complex installation, control, modification, and repair problems by studying wiring and schematic diagrams and technical publications and determining capability, capacity, and limitations of equipment, tools, and materials. Determines procedures for maintenance, installation, modification, and repair of electrical real property installed equipment and systems. Recommends revised maintenance, repair, and installation procedures to facilitate full utilization of personnel and equipment. Diagnoses recurring malfunctions and recommends corrective action, proposed modifications, or other appropriate solution.

b. *Installs, services, modifies, and repairs electrical and electronic equipment and systems.* Performs difficult tasks involving inspecting, troubleshooting, servicing, assembling, installing, connecting, adjusting, and testing all electrical distribution, control, and utilization equipment and systems rated 600 volts or less, such as fire and gas detection and warning systems, including system protective devices, explosion-proof lighting and wiring systems, high-bay and industrial shoplighting systems, security lighting, electric heating and cooking systems, electrical ground detection systems, station batteries and charging systems, generators and excitors, motors and starters, and power protective relaying systems. Performs complex testing, installation, and repair tasks, such as testing and calibrating electric power systems relays and meters, troubleshooting equipment control circuits, laying out and installation of complex conduit and wiring systems, and repair and adjustment of electrically operated circuit breakers. Installs, repairs, maintains, troubleshoots, and tests solid state electronic equipment such as motor controllers, switch gears, power supplies, lighting control systems, and electronic alarm system components. Installs, tests, and maintains electric power sources for cathodic protection systems. Installs, services, and repairs, although 600 volts is normal voltage limit, isolated de-energized high voltage equipment associated with power generation and interior distribution systems.

c. *Inspects electrical systems and equipment.* Inspects completed or in-progress work to ensure compliance with standing operating procedures, safety standards, and technical publications. Performs periodic inspections to determine safety and operational condition of electric power and control systems. Detects potential malfunctions by examining for loose connections; improper insulation; overheating of electrical systems components; and undesirable collections of dirt, grease, moisture, and corrosion on electrical equipment wiring and inclosures. Interprets inspection findings, and determines adequacy of corrective action.

d. *Performs planning activities.* Prepares facility survey schedules. Performs facility surveys. Makes on-site investigations of proposed work to determine resource requirements. Prepares cost estimates for in-service work requests. Applies Engineered Performance Standards (EPS) in planning and estimating jobs. Coordinates plans with other civil engineering and base activities.

e. *Supervises electrical personnel.* Plans and schedules work assignments. Establishes work methods, production controls, and performance standards for subordinates. Ensures availability of required maintenance equipment, tools, test instruments, and spare parts. Evaluates performance of subordinates performing installation, repair, servicing, and test functions in terms of compliance with policies, directives, and technical manuals and orders. Conducts on-the-job training of electrical personnel in installation, servicing, test, and repair of interior electrical distribution and utilization equipment and control systems.



b. *Education.* Completion of high school with courses in physics and mathematics is desirable.

c. *Experience.* Experience in functions such as installation, repair, and servicing of electrical generation, distribution, and utilization equipment and systems is mandatory.

d. *Training.* Completion of a basic electrician course is desirable.

e. *Other.*

(1) A minimum of Grade I color vision as defined in AFM 160-17 is mandatory.

(2) Physical qualification for military drivers according to AFR 160-43 is mandatory for entry into this AFSC.

### 4. *SPECIALTY SHREDOUTS

| *Suffix* | *Portion of AFS to Which Related* |
|---|---|
| F | LGM-25 |

Figure 1-4. Electrical technician.

AFSC 54290
ICEM Code 54200

### AIRMAN AIR FORCE SPECIALTY

### ELECTRICAL SUPERINTENDENT

#### 1. SPECIALTY SUMMARY

Superintends activities engaged in construction, installation, modification, operation, maintenance, repair, planning, and overhaul of interior and exterior electrical power generating and control systems; fire alarm, intrusion and control systems; cathodic protection systems; rotating and static uninterruptible power systems (UPS); aircraft arresting systems; and electrical distribution equipment. *Related DOD Occupational Subgroup* 721

#### 2. DUTIES AND RESPONSIBILITIES

a. *Plans and organizes electrical activities*. Supervises, plans, and schedules work and training assignments. Establishes performance standards and work procedures to ensure effective personnel utilization and to increase efficiency and economy of operation. Provides for and controls use of equipment, space, and supplies. Develops organizational structure to define lines of authority and assigns specific responsibilities. Programs and coordinates electrical distribution and system outages, maintenance, and repair requirements with related activities and users. Performs planning activities. Prepares facility survey schedules. Performs facility surveys. Makes on-site investigations of proposed work to determine resource requirements. Prepares cost estimates for in-service work requests. Applies Engineered Performance Standards (EPS) in planning and estimating jobs. Coordinates plans with other civil engineering and base activities.

b. *Directs electrical activities*. Supervises work accomplishment in electrical power production and aircraft arrest-barrier activities by assigning personnel to specific functions such as installation, modification, operation, maintenance, repair and overhaul of equipment. Included are gas and diesel engines, gas turbines steam generators, and rotating and static UPS; and associated electric power generating equipment to include controlling, regulating, recording and monitoring primary plant equipment and aircraft arresting systems. Directs utility electrical power construction, installation, operation, maintenance and repair activities to include high voltage work; airfield and approved lighting systems; overhead and underground distribution systems; fire alarm, intrusion and control systems; cathodic protection systems; interior electrical work; and electrical support of missile weapon systems. Establishes teams or shifts. Identifies and controls requisitioning parts, systems, fuels, lubricants, bench stock and technical publications. Ensures compliance with safety practices and regulations. Analyzes productivity and work quality. Monitors electrical generating unit records and analyses for organization, intermediate or depot level maintenance, and preparation of maintenance forms, reports and records. Issues and logs safe clearance procedures for all crafts engaged in maintenance of electrical systems and equipment.

c. *Establishes and conducts on-the-job training for electrical personnel*. Directs on-the-job training and monitors progress of personnel. Plans and conducts conferences and classes for instructing personnel on new projects, work requirements, and equipment. Arranges for attendance of selected individuals at formal and special training courses.

d. *Inspects and evaluates electrical activities*. Performs periodic and special inspections of electrical activities to ensure compliance with policies, regulations, and technical publications and to provide assistance in solving maintenance, supply, and personnel problems. Interprets inspection findings and initiates corrective action. Obtains certification of power line crew for performance of work on energized systems and certification of power production personnel in power plant, UPS and standby generator operation. Ensures adequacy of maintenance performed on power systems. Obtains special tools and equipment required for safe performance of tasks assigned.

e. *Performs technical electrical functions*. Resolves technical problems and interprets manuals and technical publications applicable to construction, installation, modification, operation, maintenance, repair, and overhaul of electrical power generating systems and aircraft arresting systems. Isolates unusual malfunctions; examines faulty components and material; and determines need for repair or replacement and need for submitting material deficiency and unsatisfactory reports under Air Force regulations. Evaluates operational effectiveness of electrical systems and recommends engineering studies examining modification of equipment and materials.



#### 3. SPECIALTY QUALIFICATIONS

a. *Knowledge*.

(1) Knowledge of the principles of electricity, electrical circuitry and distribution, internal combustion engines and other prime movers for electrical generating systems or units, characteristics, capabilities, and applications of electrical generation and distribution equipment and material such as engines, generators, rotating and static UPS, solid state components, wire conduit, motors, transformers, regulators, solenoids, circuit breakers, switches, control systems, relays and fuses, procedures for repair of high voltage circuitry and equipment, balancing of loads, installation, operation and maintenance of aircraft arresting systems, fire alarm, intrusion and control systems, cathodic protection systems, and safety rules and practices is mandatory.

(2) Knowledge of field expedient construction, maintenance, and operation, including field sanitation, first aid, and work parties, is desirable.

b. *Experience*. Qualification as an Electrical Technician, Electrical Power Line Technician, or Electrical Power Production Technician is mandatory. In addition, experience in directing functions such as inspection, operation, maintenance, and repair of interior and exterior electrical power generating equipment and systems, rotating and static UPS, and aircraft arresting systems is mandatory.



Figure 1-5. Electrical superintendent.

# Resource Management

THE MANAGEMENT philosophy of the Air Force includes getting maximum efficiency for each dollar spent while attaining planned objectives. This means that human resources must be consumed in the most effective way to meet the goals of the organization. As you supervise electrical jobs on your base, you should ask and answer these two questions: "Are the jobs being done well?" and "Is there a way to do them better?"

The key to improving jobs is not necessarily an attempt to speed up work by prodding your workers. Substandard work may be brought up to standard by better project planning, improving material support, and eliminating delays. Your coordination with the equipment shop might save many man-hours of standby time. Man-hours that are not consumed by productive work are a waste of Air Force dollars. So plan your projects well—that is, with resource management in mind.

## 2-1. Work Authorization Documents

To be an effective supervisor, you must be able to use manpower effectively. Before any work can be done by your shop, it must be authorized on some kind of "Work Authorization Document." In this section we will cover these documents.

**026. State the basic concepts of the civil engineering management system.**

**CE Management System.** You may ask the question, "Who originates all the work that my shop has to do?" The great majority of the work in civil engineering has been identified and planned ahead of time. The planning and controlling of this work could not be done without a sound management plan. The plan we are talking about is called the *Inservice Work Plan (IWP)*. This plan, like all other plans, is only as good as the information that is used for its development and the effort that is put forth to adhere to the principles and objectives of the plan.

*Planning*. Do you recall earlier an office called Resources and Requirements? Under this office is a unit known as "planning." Each year the planners visit each facility on base and thoroughly inspect it for any work that needs to be done. The inspection is called a *facility survey*. This survey is one of the inputs required by civil engineering to develop its work plan.

In addition to the facility survey, shop supervisors are responsible for two inputs to the work plan. One of them is for "recurring" labor hours, and the other is for "equipment maintenance" labor hours such as fire alarms. The recurring labor hours are for work done on a periodic basis within a particular year. An example of this work is cathodic protection readings. Another example would be relamping hangars.

After all the work inputs are sent to Production Control, the IWP programmer gathers them together and places the labor hours on a document called the IWP./n IWP. Each month work items from this plan are sent to the work control scheduling section for assignment to CE shops. These work items come on forms known as "work authorization documents." As the words indicate, these documents are the authority from civil engineering to perform the work stated on the forms.

*Performance evaluation*. Civil engineering also has a management plan. In this plan there are provisions for evaluating the performance of CE units. Using the "management by exception" technique, which compares the "estimated" versus the "actual" labor hours, industrial engineering can evaluate the performance of operations cost centers. Frequent deviations from the estimated labor hours will signal the need for further in-depth evaluations.

*Base engineer automated management system (BEAMS)*. In civil engineering a large number of records need to be kept. These records include the amount and cost of electricity consumed on base; amount of sewage disposed; labor hours required to operate power plants; size, shape, condition, and cost of each facility. Many other records are required by law to be kept. Even your name and employee number are part of the records. When information of this sort is needed, civil engineering merely asks the computer in symbols and it will furnish this information. In a matter of seconds the computer replies with up-to-date answers.

The name used to identify the automated data processing system is BEAMS. The computer used is the Burroughs 3500 (B3500). BEAMS provides a means of automating a large number of civil engineering records and files. It is of great significance that these files can be maintained with efficiency and effectiveness within the automated system; however, it is of even greater significance that they provide the information for a great variety of computer products that are available to managers on demand. These products can be, and are, used by managers to make many important decisions. Actions of most all shop workers within civil engineering affect the information within the computer files and records and ultimately influence the content of the management products. These influences are either direct as

are the actions of personnel who maintain cost, real property, work control, and programming records files, or indirect as are the actions of shop workers who report the labor hours and materials used to accomplish an assigned job. It is of utmost importance that all civil engineering personnel know that their actions directly or indirectly influence the accuracy of the information contained in the automated system and consequently the management products that the system produces. The reliability of their contribution builds their own faith in BEAMS and the decisions of those who use it.

**Exercises (026):**

1. What is the Inservice Work Plan?

2. Who performs a facilities survey and what is it?

3. Name two inputs you as a shop supervisor of the interior electrical shop, would make to the work plan and give an example of each.

4. What is management by exception?

5. What is the name of the automated computer system used to process civil engineering records?

**026a. (098—for CE feedback reference only). Identify the rationales and trace the procedures used in developing Engineered Performance Standards.**

**Engineered Performance Standards (EPS).** The estimate of labor hours to perform maintenance on real property is a major feature of the BEAMS and the IWP. Accurate estimates are essential to track the CE organization towards the maximum use of taxpayers dollars and continuously improve methods of utilizing resources.

To realize the fullest and most efficient use of available manpower and money for maintenance, Industrial Engineering procedures and techniques were applied to the idea of developing standards for maintenance work, an idea which would allow uniform and accurate estimates for labor hours. These labor estimates eventually become known as Engineered Performance Standards (EPS). These estimates of labor hours for maintenance are used in the BEAMS today.

EPS represents the average time necessary for a qualified worker, working at a normal pace under capable supervision and experiencing normal delays, to perform a defined amount of work of a specified quality, while following acceptable trade methods. In other words, it is the amount of time an average craftsperson should take to perform a given amount of work.

EPS is a tool used by planners to obtain consistent estimates of man-hours for maintenance work. When this tool is used properly, any planner and estimator having a working knowledge of craftwork can develop good man-hour estimates. These EPS estimates can then be used to provide data for necessary maintenance management decisions. Planning, scheduling, and management analysis of performance are based on EPS.

EPS data for planners and estimators is found in Air Force publications (AFM 85-series) as 14 craft handbooks. Each handbook pertains to only one specific craft, such as carpenter, electrician, or mason. Also included is the Summary of General Data that pertains to general data common to all crafts, such as job preparation time, craft delay allowance, travel time, and material handling.

**EPS Development.** There are three techniques used by Industrial Engineers and Technicians to develop EPS.

*a. Methods time measurement.* MTM is a system of predetermined time standards for basic motions such as reach, grasp, move, etc., measured in Time Measurement Units (TMUs). MTM is used in the development of EPS formulas because the method of work accomplishment is precisely and uniformly described by the list of basic motions used to measure the elements.

*b. Time study.* Time study is a method of accurately measuring work, normally with the use of a stopwatch. In EPS development it is used to determine the amount of time elements not fully controlled by workers; for example, machine time, filling a tank, or driving a piling. It is also used to verify overall times developed by one of the other techniques. However, the most frequent use of time study is made to determine travel zones at each activity.

*c. Work sampling.* Work sampling is a work measurement technique used primarily to determine percentages of work or delays as a part of the total time expended. For example, by observing workers on the job at several random times within a longer period of time, the portion of time they were working as opposed to not working can be determined. If they were found to be working 82 observations out of a total of 100, they would be working 82 percent of the time. Through the use of more detailed work sampling, the 18 percent of nonworking time can be broken down into personal time, unavoidable delays, planning, etc. Work sampling is the technique used in EPS to determine these percentages.

Studies of maintenance work begin with a visit to the maintenance shops to examine the workload. Work accounting for the largest portion of overall shop man-hours is examined first, with less frequently performed work being looked at later. After locating field work where a large number of manhours are being spent, workers are observed and actions taken to accomplish the job are then noted. No stopwatch or wristwatch is necessary here, although some random times are taken to verify the overall time spent on a particular task. Back in the office, the engineer or technician is able to breakdown the recorded units of work into smaller units of work for which

predetermined times have already been established. Then, knowing the amount of time required for these very small portions of work enables reconstruction of the larger unit of work and its corresponding time. This breakdown of work is part of the formula development, which is used in the EPS handbooks.

With the use of formulas, work of a specific nature can be grouped together. Development of a formula begins with the *element* which may be defined as a composition of basic motions and/or machine or process activities which are distinct, describable, and measurable.

The next stop in the EPS development procedure is combining a series of elements to form an operation. An *operation* may be defined as a series of actions by workers that result in a desirable change in the location or condition of maintenance material or parts.

To bring formula-derived information to readily usable form for planning and estimating, it must be carried one step further to the task-time standard level. A *task* is defined as the specific amount of work that can be performed by a single craft and specifies the time required to accomplish that work. The task is a combination of the operations required to complete work defined in the task description. Each task-time standard shows man-hours required to perform the work described and is used as a basis for information presented in the craft handbooks.

Once the planning and estimating function has completed a work-plan sequence, finalized a material requirements list and man-hour estimates for a given job, a preliminary schedule is made to determine the time frame required for receipt of all materials. Once all material is on hand and necessary equipment is available, the work is scheduled for a definite starting date. In most cases maintenance shop supervisors are consulted prior to final scheduling. It is then the supervisor's job to see that the work is accomplished in the most efficient manner.

Maintenance management is not complete without an examination of the efficiency and effectiveness of the work being accomplished. During job performance, continuous monitoring of the man-hours takes place through labor reporting. Upon completion of the work, data is compiled showing estimated versus actual manhours, labor costs, and material costs. Corrective action on any variances is then started to eliminate the recurrence in future jobs. It gives management the information necessary to bring the efficiency and effectiveness of performing maintenance up to peak operating levels.

**Exercises (026a):**

1. What is the primary reason EPS were developed?

2. Who developed EPS?

3. EPS were designed to be used for what type of work?

4. What is meant by Methods Time Measurement?

5. What industrial engineering technique measures work output with a stopwatch?

6. What is meant by the work sampling technique?

7. What is the task-time-standard used for?

8. What series of AF publications contain EPS data for planners and estimators?

**027. Identify forms, rationales, and examples of work related to the Recurring Maintenance Program.**

**Recurring Maintenance Program (RMP).** Recurring work is made up of the RMP, the operations and services work program, and other recurring work for which the scope and level of work is known without a prior visit to the job site each time the work is scheduled. The BEAMS RMP is an automated schedule for work to be done The RMP schedule is filled out by the shop supervisor and sent to the superintendent for approval. Examples and instructions on how to fill it out are found in Chapter 10 of AFR 85–1, *Resources and Work Force Management*.

Recurring maintenance applies only to equipment and real property maintained by BCE. The procedures are as follows:

*a*. Items included in the RMP are limited to items whose scope and frequency requirements are known and must be done at least once a year but not daily.

*b*. Items with a replacement cost of less than $250 are not included unless failure seriously impacts the mission or results in damage to high value items.

*c*. Superintendents must approve all items included in the RMP.

*d*. The RMP program in the BEAMS is used to maintain an inventory, schedule tasks, and report completion of the RMP work. Production control loads RMP data into the BEAMS files.

*e*. An Air Force Form 1841, Maintenance Action Sheet (MAS), is used to identify maintenance actions. An example of a MAS is shown in figure 2-1. A master copy of your shop MAS is kept in production control for audit purposes.

*f*. The superintendent reviews the shop's RMP items periodically to make sure only essential work is included.

Some of the work in the electrical career field could fall under the RMP. Some examples are listed below:

*a*. Calibrating thermostats on deep-fat fryers.
*b*. Maintaining emergency lights.
*c*. Reading static grounds.
*d*. Reading lighting protection.
*e*. Cathodic protection maintenance.
*f*. Fire alarm maintenance.
*g*. Intrusion alarm maintenance.

Items that are not included in the RMP are:

*a*. Equipment items maintained by contract services and equipment items maintained or checked daily.

*b*. Equipment items used daily by operators. Bases can include equipment items that have manufacturer-suggested maintenance tasks, or those equipment items that pose potential fire or safety hazards.

*c*. Items of equipment that are more economical to maintain and repair on an as-required basis.

*d*. RPIE (Real Property Installed Equipment) items related to missile facilities when maintenance procedures are established by the command.

*e*. Appliances.

*f*. Operations and services work items.

**Exercises (027):**

1. What is the Recurring Maintenance Program (RMP)?

2. What AF form is used to identify maintenance actions and who fills it out?

3. Who reviews the shop's RMP items and for what reason?

4. List three examples of work in the electrician career field that falls under the recurring maintenance program.

| FACILITY NO. | ACTIVITY OR STREET ADDRESS | DATE | TIME | JOB ORDER NO. |
|---|---|---|---|---|
| 1100 | TEST PAD | 25 APR 84 | 1120 | 3-2215 |

| NAME AND GRADE OF REQUESTOR | PHONE NO./ALTERNATE | COLLECTION WORK ORDER NO. |
|---|---|---|
| MSgt POllOCK | 2216/2219 | |

**SERVICE REQUIRED**

REPAIR EMERGENCY LIGHT, NE CORNER OF CONTROL CAB

| ZONE NO. | TYPE OF SERVICE | | | |
|---|---|---|---|---|
| 5 | | EMERGENCY | | SMART |
| | | URGENT | | MFH |
| | X | ROUTINE | | MC |

| WORK ID CODE | EST. TOTAL TIME |
|---|---|
| | |

| REQUIRED COMPLETION DATE | ESTIMATED COMPLETION DATE | CREW SIZE | EST. TOTAL TIME |
|---|---|---|---|
| | | | |

**AREA/FACILITY WHERE JOB IS LOCATED**

**DANGEROUS CONDITIONS EXISTING** *(If any)*

NOISE HAZARD

**RESTRICTIONS** *(time, entry, security)*

**REMARKS** *(Tools, equip., materials, special craftsman multi-shop notes, etc.)*

1 ea 12 Volt Jell-cell battery, Verta-Ray PN 6-P-12VAC

6 ft. Stepladder

| MAKE OF EQUIPMENT | TYPE/SIZE OF ITEM | COLOR OF ITEM |
|---|---|---|
| VERTA RAY | 2 HEAD EMERG/LIGHT | N/A |

| ASSIGNED TO | DATE | TIME | COMPLETED BY | DATE | TIME | INITIALS | LUC 12 | LUC |
|---|---|---|---|---|---|---|---|---|
| 471 | 16 MAY | 0700 | AMN SMITH | 16 MAY | 0900 | JEP | | 2 HRS |

| REFERRED TO | DATE | TIME | COMPLETED BY | DATE | TIME | INITIALS | LUC 12 | LUC |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

| DEFERRED TO | DATE | TIME | DISPOSITION | AUTHORIZED |
|---|---|---|---|---|
| | | | | |

AF FORM FEB 82 1879 PREVIOUS EDITION WILL BE USED. SHOP COPY BCE JOB ORDER RECORD

Figure 2-3. Sample, AF Form 1879.

| BCE MULTI-CRAFT JOB ORDER | | | JOB ORDER NO. M0-26 |
|---|---|---|---|
| COST CENTER 457 | COLLECTION WORK ORDER NO. 06245 | FACILITY NO. 1200 | DATE PREPARED 26 JUNE 81 |
| NAME OF INSPECTOR Potts, J. SSgt. | USING AGENCY 26 FMS | INDIVIDUAL TO CONTACT (Name & Phone No.) Potts, SSgt. 2230/2259 | |

| WORK DESCRIPTION | LOCATION | MATERIALS ITEM | MATERIALS QNTY | MATERIALS U/M | M/HR. EST. | CRAFT | INCOMPLETE WORK |
|---|---|---|---|---|---|---|---|
| REPL WINDOW | EAST SIDE | 48" X 48" | 1 | EA | 2 | CARP | |
| REPL SINK | Latrine | SINK | 1 | EA | 2 | PLUMB | |
| REPAIR EX. LIGHTS | E. HALLWAY | EXIT LIGHT | 1 | EA | 1 | Int. Elect. | |

AF FORM MAY 76 1219 PREVIOUS EDITION IS OBSOLETE.

| WORK DESCRIPTION | LOCATION | MATERIALS ITEM | MATERIALS QNTY | MATERIALS U/M | M/HR EST | CRAFT | INCOMPLETE WORK |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

| TOTAL ESTIMATED MAN HOURS | CARP. | PLUMB. | ELEC | PAINT | OTHER | TOTAL | TOTAL ACT. HRS |
|---|---|---|---|---|---|---|---|
| | 2 | 2 | 1 | | | 5 hrs. | |

REMARKS

SIGNATURE OF INSPECTOR: SSgt. JERRY POTTS

| DATE ASSIGNED | AUTHORIZING SIGNATURE |
|---|---|
| 21 JULY 81 | Robert L. Horse |
| DATE COMPLETED | SUPERVISOR'S SIGNATURE |
| 9 AUG. 81 | Robert L. Horse |

Figure 2-4. AF Form 1219.

| 1. INSTALLATION NAME | 2. WORK REQUEST NO. | 3. PROJECT NO. | 4. REQUESTER'S NAME AND PHONE NO. | ORDER NO | | NO. |
|---|---|---|---|---|---|---|
| A. CONTROL Sheppard AFB TX<br>B. OTHER Reese AFB TX | 4540 | | Col Robert Fisk | | 15 | A-2221 |

5. STATEMENT OF WORK

13 AUTHORIZATION
A. SIGNATURE: Chief of Resources
B. DATE: 27 May 83

14 COMPLETION
A. SIG OF COST CENTER SUPVR: Supervisor
B. COST CENTER NAME 471: Interior Electric
C. ACTUAL COMPLETION DATE

15 TOTAL ESTIMATED COST

9. WORK ORDER MASTER FILE *(Remote Input Format) (Card Columns 1–109)*

| TRANSACTION IDENTIFIER 1-7 | 8 | CONTROL INSTL 9-12 | C C 13 | WORK ORDER NO. 14-18 | 19 | T N 20 | W I 21 | NR SH 22-23 | INSTL INDICATOR 24-27 | W C 28 | RRI 29-30 | FACILITY I.D. NO. 31-35 | FAC SUF 36-37 | COST ACCOUNT 36-42 | P R 43 | C I 44 | G Q 45 | WORK DESCRIPTION 46-75 | S I 76 | ORG CODE 77-79 | T I 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WCM-ACD | , | REES | | B1038 | ' | 1 | A | 01 | NQRO | C | EE | Ø0216 | | 51035 | 2 | | | REPLACE MAIN PANEL | | 471 | |

9. CONTINUATION OF REMOTE INPUT FORMAT

10. INPUT FORMAT WHEN USING PSEUDO REMOTE

CARD COLUMNS 1-80 - USE FORMAT ABOVE FOR TRANSACTION NO. 1
CARD COLUMNS 1-48 USE FORMAT BELOW FOR TRANSACTION NO. 2

| WO OPENING DATE 81-86 | EST. START DATE 87-92 | EST. COMP. DATE 93-98 | EST. NON-AF EXCESS MAT. 99-105 | R C 106 | O S 107 | F I 108 | O T 109 | RES 110-111 | REPEAT CARD COLUMNS 1-19 ABOVE 1-19 | T N 20 | WO OPENING DATE 21-26 | EST. START DATE 27-32 | EST. COMP. DATE 33-38 | EST. NON-AF EXCESS MAT. 39-45 | R C 46 | O S 47 | F I 48 | RES 50-51 | BLANK 52-80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 2 | | | | | | | | | |

11. WORK ORDER SHOP FILE *(Remote/Pseudo Remote Input Format)*

| TRANSACTION IDENTIFIER 1-7 | 8 | CONTROL INSTL 9-12 | C 13 | WORK ORDER NO. 14-18 | COST CENTER 19-21 | 22 | NO. REQUIRED 23-25 | ESTIMATED LABOR HRS. 26-30 | ESTIMATED SHOP RATE COST 31-37 | ESTIMATED DIRECT MATERIAL COST 38-46 | ESTIMATED PROJECT CONTRACT COST 47-55 | ESTIMATED SERVICES CONTRACT COST 56-64 | ESTIMATED OTHER COST 65-73 | BLANK 74+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WCN-ADD | , | REES | | B1033 | 8471 | ' | ØØ9 | Ø16Ø | | | | | | |
| WCN-ADD | , | | | | | . | | | | | | | | |
| WCN-ADD | , | | | | | . | | | | | | | | |
| WCN-ADD | , | | | | | . | | | | | | | | |
| WCN-ADD | , | | | | | . | | | | | | | | |
| WCN-ADD | , | | | | | . | | | | | | | | |
| WCN-ADD | , | | | | | . | | | | | | | | |
| 12 TOTAL | . | | | | | | | | | | | | | |

AF FORM 327 FEB 81 PREVIOUS EDITION IS OBSOLETE. BASE CIVIL ENGINEER WORK ORDER

Figure 2-5. AF Form 327.

47

15

661

360

BEST CO

Air Force Form 561 is released to workers and logged by controllers. Based on decisions of the supervisors, controllers sequence follow-on assignments and relay instructions to the workers. The objective is to know the location of each worker and the status of all work. You may be called on to work with the scheduler in filling out a 561; therefore, you should be familiar with this form. An example of this form is shown in figure 2-6.

**Exercises (031):**

1. In the space provided, state the type work order required for each of the following job situations.

   a. No power to compute center.

   b. Porch-light inoperative in family housing.

   c. Install indirect lighting in the commander's office.

   d. Assist a SMART team by replacing a broken receptacle cover.

2. Who manages AF Form 561, BCE Weekly Work Schedule?

3. State the objective of AF Form 561.

## 2-2. Property Accountability and Responsibility

It is important that you understand your responsibility for Government property. If you are careless when placed in charge of Air Force property you may pay for a piece of equipment for which you damaged or lost. Your knowledge of the rules and procedures will make you conscious of your responsibility for government property.

**032. Associate the type of property responsibility, liability, or form with the appropriate identifying statements.**

**Property Accountability and Responsibility.** The organizational commander is responsible and accountable for all property that is issued to his organization, whether he signs for it or not. But because the duties of the commander make it impracticable for him to exercise personal supervision of the supply functions, a commander designates an officier to act as his supply officer. The commander or his supply officer may then name other representatives to receive and sign for property in his name. However, delegation of duty does not make the commander exempt from financial liability for loss, damage, or destruction of property.

Property responsibility means that each one of us is obligated to take care of Air Force property, whether it has been issued to us or to our unit. This will include pecuniary liability.

When you buy an article from a store, the moment the sales clerk completes the sale, the store drops its accountability and responsibility for whatever use you make of it. Similarly, when a stock clerk issues an AF item to you, accountability is dropped insofar as the issuing authority is concerned. However, you do not become the owner of the item; instead, the Air Force keeps ownership, and you assume responsibility for the care and protection of the item.

*Supervisory responsibility.* Supervisory responsibility applies to any person who exercises supervision over property received, in use, in transit, in storage, or undergoing modification or repair. Supervisors are responsible for selecting qualified personnel to perform the duties under their control and for properly directing or training them. They instruct their people in supply procedures in order to make sure of compliance with Air Force regulations governing property. Supervisors are also responsible for indoctrinating their personnel in the principles of supply discipline.

*Custodial responsibility.* Any individual who has acquired possession of Government property has custodial responsibility for it. Individuals are personally responsible for such property if it is issued for their official or personal use, whether or not they have signed a receipt for it. They are also personally responsible for any property under their direct control for storage, use, custody, or safeguarding.

"Finders, keepers" may apply in some circumstances but not to Government property. If you find Government property that may be lost, stolen, or abandoned you must assume custodial responsibility for it, and you must protect or care for it until it can be returned to the proper authorities. Personnel may be relieved of responsibility for a particular piece of property in a number of ways, depending upon the circumstances. For example, property may be turned back to base supply as being excess to the unit's needs. Other items may be transferred from the responsibility of oone person or organizaiion to that of another. Still other items may be damaged or lost through carelessness of the one that has custody, in which case the person may be held liable and may have to pay for them by deductions from their pay.

**Pecuniary Liability.** The word "pecuniary" means money. Personnel having property responsibility also have pecuniary liability to make good property loss, destruction, or damage due to their maladministration or negligence. Pecuniary liability may be shared by persons having command, supervisory, or custodial responsibility. If a person pays for an item of Government property, the property remains the possession of the Government. This

| TO | FROM | SIGNATURE | DATE | ACTION TAKEN |
|---|---|---|---|---|
| | | | | APPROVED ☐<br>DISAPPROVED ☐ |
| | | | | APPROVED ☐<br>DISAPPROVED ☐ |
| | | | | APPROVED ☐<br>DISAPPROVED ☐ |
| | | | | APPROVED ☐<br>DISAPPROVED ☐ |
| | | | | APPROVED ☐<br>DISAPPROVED ☐ |
| | | | | APPROVED ☐<br>DISAPPROVED ☐ |

1. CUSTODIAN REQUEST NO.: IN 4081

8. IN-USE DOC NO.:

9. NATIONAL STOCK NO. OR PART NO.: 6625-01-083-5979

2. CMO:  3. FAD: 4  4. UJC:  5. BUD:

10. USE CODE:  11. PRICE: 400.00  12. U/I: ea  13. ERRCD:

6. CUSTODIAN SIGNATURE

14. EQUIP CODE  15. NOMENCLATURE

7. *I certify that I have evaluated this request and the action herein is required.*

SIG OF ORGN COMDR *(Not required for turn-in)*

| 16. ALLOWANCE IDENTIFICATION | | | | | 17. QUANTITY | | | |
|---|---|---|---|---|---|---|---|---|
| ASC | COMPOSITION CODE | | | | IN USE | CURR AUTH | NEW AUTH | NO REQ'D |
| | PART | SECT | SUB-JECT | COL | | | | |
| | | | | | 0 | 1 | | 1 |

18. ACTION REQUESTED

A. AUTHORIZATION
INCREASE ☐  ADD NEW ☒  REDUCE ☐  DELETE ☐

B. ISSUE/DUE OUT  ADVICE CODE (   )
INITIAL ISSUE ☒  REPLACEMENT ☐  CANCEL DUE OUT ☐

C. TURN-IN *(Complete all applicable blocks)*

| CONDITION | | STATUS | YES | NO |
|---|---|---|---|---|
| SERVICEABLE | | COMPLETE *(List missing parts in Block 19)* | | |
| REPARABLE | | CALIBRATION REQUIRED | | |
| CONDEMNED | | CLEAN, PAINT, ETC. | | |
| UNKNOWN | | DISASSEMBLY REQUIRED | | |

DATE AVAILABLE FOR PICKUP

19. JUSTIFICATION AND ITEM DESCRIPTION

Vibroground w/Acc Case
One per organization authorized to perform routine maintenance in accordance with AFR XX-XX and TO XXX-XXX-X. This item is necessary for calibration of Cathodic Protection Systems in Service.

20. REVIEWING AUTHORITY COMMENTS

| 21. ORGN | | | 22. UKC | | | 23. LEVEL | | | 24. DET | | | 25. WRM | | | 26. EMOLOC | | | 27. SUPPLY CONTROL NO. | | | | | | | 28. CEMO CONTROL NO. | | | | | | | 29. AFLC CONTROL NO. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

AF FORM 601 NOV 81  REPLACES AF FORMS 601A, APR 68 AND 601B, APR 70 WHICH WILL BE USED

**EQUIPMENT ACTION REQUEST**
*(See Instructions on Reverse)*

Figure 2-10. AF Form 601.

**Exercises (034):**

1. Who accounts for nonexpendable equipment as recorded in base supply?

2. Why do you inventory your account periodically?

3. What is AF Form 126 used for?

4. What must be done before a new custodian takes over an equipment account?

5. What is AF Form 601 used for?

6. What TA is the main source for individual clothing and equipment allowance?

**035. State the procedures used to order materials for BCE job orders and service calls and name the section you must go through for approval.**

**Material Control Support.** The material control section processes request for materials, monitors the status of requirements, and gives information on the availability of material. This section controls all material needs in the BCE organization except janitorial and administrative supplies.

This unit follows procedures set up by AFM 67-1, *USAF Supply Manual*, Volume II, Part 2, Chapter 19. A BCE central tool control center is used to provide all shop tools, tool kits, and so forth. Material control manages a centralized bench stock at some bases.

Materials are requisitioned by the planning section of BCE, the service call desk for job orders, and by you or the people in your shop. You will complete an AF Form 1445, Materials and Equipment List, as shown in figure 2-11. The form is routed through the service call desk and controller. They will enter the job order on it and send it to material control. When the materials are received, the job can be finished.

AF Form 1445 is used for all material requests except for Base Service items, individual equipment and tool issue items, EAID items, and bench stock replenishment. When you pick up materials from the BCE holding area, take the AF Form 1445 with you and compare the materials you are picking up against the items on the form. Check the nomenclature to be sure that the item you are to pick up is the same as the one described on the form. Also, check the unit of issue to make sure that they agree with what you are picking up. If these items do not agree, don't sign for any of the items. Report any discrepancies to material control.

**Exercises (035):**

1. What BCE section controls the materials you will receive in your shop?

2. Where must you route an AF Form 1445 before it goes to Material Control?

3. Why should you take your copy of AF Form 1445 with you when picking up materials?

**036. Specify the procedures that pertain to the establishment of bench stock.**

**Bench Stocks.** A bench stock of common nonrecoverable hardware items, such as nuts, bolts, and screws, must be established in each shop. Bench stock is made up of low cost, expendable items which, due to regular use, are put at the point of use before actual use or need. The main advantage to this system is that the items are available to the user at once. Failure to maintain adequate bench stock items and levels can disrupt your work schedule just as much as nonavailability of workers. Although not repairable themselves, bench stock items are needed to repair other items. The on-hand quantity of bench stock items does not normally exceed a 30-day issue requirement, except where the unit of issue is package, kit, etc. When it is considered feasible, the package or kit is issued as bench stock.

*Establishing bench stock.* When a bench stock is authorized, a list of the required items and quantities is submitted to Material Control. Material Control and the base supply bench stock unit then review the list to determine if demands justify the items and quantities requested.

Each bench stock item is assigned a 4-digit serial number by the bench stock support unit. This number serves as the bench stock and bin location identifier and is part of the 14-digit document number for all supply transactions. Each item retains this item serial number until it is deleted from bench stock, even though the stock number may change. The document number contains the following data: the first digit, bench stock code (always B); the next three digits, the organizational code; the next two digits, the shop code; the next four digits, the date of the last demand; and the last four digits, the item serial number.

*f.* When the security of a ladder is endangered by other activities, rope off the area around it, fasten it securely, and assign someone to study the bottom.

*g.* When you use a ladder in front of a door, lock the door or block off the door and route personnel to another exit.

*h.* Never leave a ladder unattended for any length of time while it is erected—take it down and lay it on the ground.

*i.* When working from an extension ladder, stand no higher than the third rung from the top and do not attempt to reach beyond a normal arm's length.

*j.* If you need help to do the work, have your helper get another ladder—don't allow anyone on the ladder with you.

*k.* Never climb a ladder while using both hands to hold material; at least one hand must be used while climbing or descending a ladder.

*l.* Never place either the top or bottom of a ladder against unstable material.

*m.* Before climbing a stepladder, be sure it is fully open and locked and that all four legs are on solid footing.

*n.* Do not leave tools on top of a stepladder unless it is equipped with a special holder.

*o.* Do not stand on either of the top two steps of a stepladder.

*p.* Never use metal ladders where there is a possibility of coming in contact with electric current.

*q.* Get help when erecting long, heavy ladders.

**Exercises (089):**

1. Match each of the following situations in column B with the applicable safety precaution in column A.

| *Column A* *Safety Precaution* | *Column B* *Situation* |
|---|---|
| ____ (1) Safety shoes. | a. Climbing a ladder. |
| ____ (2) Do not stand on two top steps. | b. Working from an extension ladder. |
| ____ (3) Rope off the area. | c. Before climbing a stepladder. |
| ____ (4) Do not use near electrical apparatus. | d. Using stepladder. |
| ____ (5) Stand no higher than third rung from top. | e. Be sure ladder rails are equipped with these before climbing. |
| ____ (6) Face the ladder and use both side rails. | f. Use metal ladder. |
| ____ (7) Be sure locking device is locked. | g. Ladder placed in area of other activities. |

**089a (099—for CE feedback references only).** Restate requirements related to hazardous waste concerning the program goal, specific vulnerabilities and disposal procedures.

**Hazardous Waste Program.** Another area you should be aware of, as an electrician, is a possible contact with HAZARDOUS MATERIAL (HM) and HAZARDOUS WASTE (HW). There is a wide variety of compounds classified as HM, (over 3,000) while they are in use, in storage, and during disposal. In the last stage the materials become hazardous waste. To comply with Federal, State, local and Air Force regulations, a program has been established to insure identification of HM and track the materials from issue, through the useful life of the materials, to the eventual disposal of the hazardous waste biproducts. The entire HM and HW program is to prevent contaminating water supplies or the environment and protecting personnel.

Every Air Force installation should have an HW management plan. The plan should explain the following procedures:

Waste packaging.
Storage of waste.
An inspection plan.
Personnel training.
Fire protection.
Emergency assistance.
Evacuation and clean up.
Recordkeeping.

The plan should list all areas on the base that generate HW, what type of containers are used to package the waste in, where to take the containers for disposal, and how the disposal will take place. Disposal may require HW to be reclaimed, burned, or buried. HAZARDOUS WASTE MUST NEVER BE POURED IN SEWERS, IN DRAINS, OR DUMPED ON THE GROUND.

Vapors from volatile solvents, fuels, and oils may travel a considerable distance in certain soils and form an explosive concentration. Waste with a high solid content may form an explosive gas as they decompose.

**Specific Vulnerabilities.** Hazardous wastes generated at Air Force bases are mainly products of metal plating shops, aircraft and vehicle washing racks, and shops that clean engine parts and in laundry and dry cleaning operations. In the electric shop, you may encounter HM, such as paint, solvent, oil, grease, detergent, and acid and compounds used for electrical insulation, such as polychlorinated byphenyls (PCBs).

PCBs should be considered extremely hazardous. Their presence in the environment has been proven to cause disease and possibly cancer. Federal law now prohibits the manufacture of PCB in any form. The Toxic Substance Control Act of 1976 is specific towards the controls and procedures established for the operation, maintenance, storage, and disposal of PCB equipment. PCB is found in all electrical capacitors unless the capacitor is marked "No PCBs." Other areas you should be aware of as possibly containing PCB's are large, oil-cooled transformers, ballasts in fluorescent lights, power filter equipment for computers, and radio interference filters. USE EXTREME CAUTION when you open filter boxes and electrical panels.

**Disposal Procedures.** You should request that your supervisor explain the local procedures for spilled chemicals. Usually, a liquid is covered by an absorbent material. A dry spill is covered with a plastic tarpaulin to prevent it from becoming airborne. PCB leaks or spills should be removed completely. The cleanup material, rags, and any contaminated clothing should be placed in a standard steel 1-gallon or 5-gallon paint can. The can must have metal-to-metal lid seals and must be sealed with tetrafluoroethylene pipe dope. The cans should be marked as containing PCB and routed to the place designated by the bioenvironmental engineer. Adequate cleanup of spills is essential to remove any health or environmental hazards. When cleaning up spills, it is advisable NOT TO WORK

ALONE. Make sure that the area is properly ventilated and that appropriate protective equipment is used.

**Exercises (089a):**

1. What is the goal of the hazardous material program?

2. How may hazardous material/waste be disposed of properly?

3. Hazardous waste must never be poured in ______________, in __________, or dumped ______________.

4. List the hazardous materials you may encounter in your shop.
   a.

   b.

   c.

   d.

   e.

   f.

   g.

5. What are the disposal procedures to take for a liquid or dry chemical spill?

**090. From a list of presumed safety precautions related to handling chemicals or chemical solutions, distinguish between safe and unsafe precautions.**

**Chemicals and Chemical Solutions.** The types of chemicals with which you will most likely be concerned are those used for storage batteries. The chemicals are used as electrolyte for the batteries. The two you may come in contact with are sulfuric acid, used in lead-acid batteries, and potassium hydroxide, used in the nickel-cadmium batteries.

*Sulfuric acid*. The first precaution to observe in working with acids is the process of mixing them. The proper mixing procedure is always to add the acid to the water. Pouring small amounts of acid into a larger volume of water allows adequate cooling of the mixture. If this mixing procedure is reversed by pouring water into the acid, a violent reaction may occur and acid may be splashed over a wide area.

Sulfuric acid is dangerous to any part of your body, especially to your eyes. In the event of any contamination, the affected area must be flushed immediately with a solution of bicarbonate of soda and water. If the eyes become contaminated, immediately flushing with large volumes of water is important, and expert medical aid should be obtained at once. Sulfuric acid will also damage clothing, shoes, or just about anything with which it comes in contact. One more hazard of this unpleasant material is its possible explosion hazard. When a battery containing sulfuric acid is being charged, a quantity of hydrogen gas is given off. This hydrogen gas is highly explosive. For this reason, battery rooms or other battery charging areas must always be considered as no smoking areas.

*Potassium hydroxide*. This is ot an acid, but its use requires the observance of certain safety precautions. Potassium hydroxide (KOH) is very dangerous to the skin and eyes. It destroys tissues and causes severe burns. Breathing the vapors may result in injury to the respiratory system. Some safety precautions that you must observe in handling any battery electrolyte are listed as follows:

- Always wear full protective clothing, including gastight goggles.
- Use safety showers and eyewash fountains immediately upon contamination.
- Neutralize and flush all contaminated areas and equipment.
- Keep all battery areas well ventilated and do not breathe vapors from batteries.
- Treat lead-acid-type battery areas as no smoking areas.

**Exercises (090):**

1. If the following precautions are safe, place an "S" in the blank space. If they are unsafe use a "U" and correct them.

____ a. Use full protective clothing when handling electrolyte.

____ b. Medical aid is not needed if eyes are flushed with water after being contaminated.

____ c. Ventilation is unnecessary for potassium hydroxide.

____ d. The proper mixing procedure for mixing acids is always to add the acid to the water.

____ e. Treat lead-acid-type battery areas as no smoking areas.

**091. Match types of flammable material with the classes of fire, and state the extinguishing agent to use on various types of fires.**

**Fire Prevention.** Although firefighting is the prime responsibility of the fire department, it is your job to prevent fires and to help put them out if they do start.

Good housekeeping is essential in the prevention of fires. If you let trash, waste, dust, and other residue build up, they become a source of fire. Oily rags, for example, can ignite by spontaneous combustion. You can prevent fires of this type by storing oily rags in a metal container with a lid (see fig. 4-13).

Another serious fire hazard is the accumulation of fuel vapors, gases, paint vapors, and other items of this nature. To eliminate this type of hazard, keep your shop clean and well ventilated. Prevent fires whenever you can, but also know something about the four classes of fires and something about how to fight them.

**Classes of Fires.** You can put out fires in each of the four classes by the use of a particular action or extinguishing agent. Some fire extinguishers do not work well on all classes of fires. Water, for example, may cause an oil fire to spread rather than put out the fire.

*Class A fires.* Class A fires are those occurring in wood, clothing, paper, rags, and other items of this type. This type of fire can usually be put out with water. Water provides the cooling and quenching effect necessary to extinguish class A fires. You may also use the soda-acid-type extinguisher on this class of fire. Another type of extinguisher you can use on class A fires is the foam type. You may also use foam on class B fires.

*Class B fires.* Class B fires are those occurring in flammable liquids such as gasline, fuel oil, lube oil, grease, paints, etc. The agents required to put out this type of fire are those which will blanket the surface of the fire. This action creates a smothering effect. The types of fire extinguishers for use on class B fires are foam, carbon dioxide ($CO_2$), and dry chemical. The dry chemical units contain a dry powder, usually sodium bicarbonate, and an activating agent of $CO_2$ or nitrogen gas. The dry chemical extinguisher is also used on class C and D fires.

*Class C fires.* The class C fires are fires in electrical equipment and facilities. The extinguishing agent for this type of fire must be a nonconductor of electricity and must provide a smothering effect. The dry chemical extinguisher is used for this purpose.

*Class D fires.* The class D fires occur in combustible metals such as magnesium, potassium, powdered aluminum, zinc, sodium, titanium, zirconium, and lithium. The extinguishing agent for this type of fire must be a dry-powdered compound which creates a smothering effect.

If you discover a fire, you should take certain actions. First, sound the alarm and alert all personnel. Second, you must call the base fire department and give exact directions to the location of the fire. You should take these first two actions quickly. Then, the personnel in the area should apply the most effective means available to put out or to contain the fire. When assigned to a new shop, you should find the fire extinguisher in the area. Also find out what types of extinguishers are available and how to operate them. This information is usually printed on the fire extinguisher.


Figure 4–13. Fire prevention at work.

**Exercises (091):**

1. Match the class of fire in column B with the flammable material in column A by placing the letter in the appropriate blank.

| *Column A* | *Column B* |
|---|---|
| _____ (1) Magnesium. | a. Class A. |
| _____ (2) Electrical equipment. | b. Class B. |
| _____ (3) Paper and rags. | c. Class C. |
| _____ (4) Gasoline and grease. | d. Class D. |

2. Name three types of extinguishing agents that are used on paper and wood fires.

3. What three types of extinguishers are used on gasoline and oil fires?

4. What type extinguisher is used on electrical fires?

### 4-3. First Aid

Of all the the different tasks or jobs that you perform, knowing and being able to apply first aid procedures is one of the most important. In this section we will talk about the first aid you should know. This will include artificial resuscitation, closed chest cardiac massage, bleeding, protecting and treating wounds, heat exhaustion, and shock. This section is not intended to qualify you as a doctor or a medical person, but it may help you save a life.

Figure 4-20. Two-person rescue position.

NOTE: With a child, use only one hand and relatively light pressure. In newborn infants, the use of fingers only may be sufficient.

Release the pressure immediately, lifting the hands slightly (see fig. 4-22), then repeat in a cadence of approximately 60 thrusts per minute.

(5) Continue steps. Continue closed chest cardiac massage until you get professional medical aid. Also, continue to give mouth-to-mouth resuscitation until help arrives. If you are on your own and the victim shows no response, continue both measures until the victim becomes stiff (rigor mortis sets in). Even trained and experienced medical personnel find it increasingly difficult to say when a person is really dead beyond recall. Again, the most important point is to immediately begin and continue resuscitation efforts.

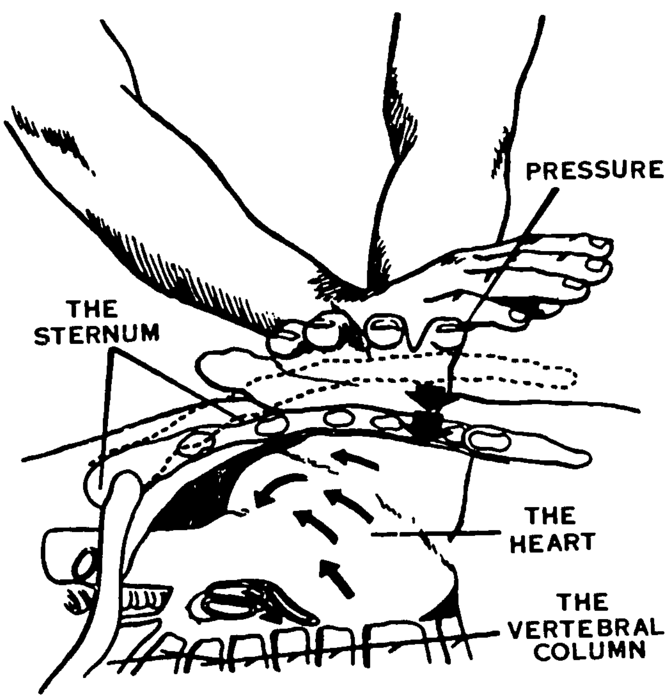


Figure 4-21. Placement of hands.

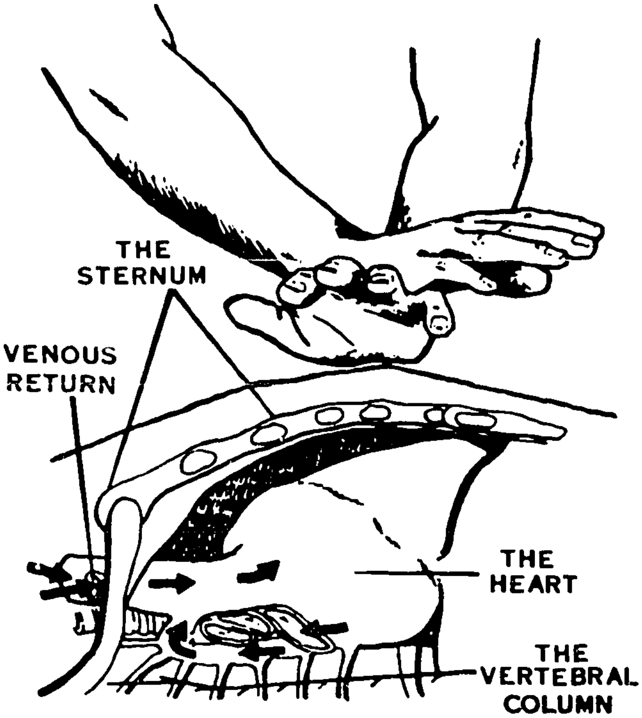


Figure 4-22. Releasing pressure.

*Precautions.* Care must be taken in administering closed chest cardiac massage. Follow the above procedures carefully regarding the placement of hands and force applied in order to avoid complications, such as fractured ribs or injury to the spleen, liver, or other organs.

*Care of the patient.* An unconscious person becomes cold very rapidly, and chilling means a further strain on a vitality already weakened. Experience has shown that the cold to which the victims of gassing, electric shock, or drowning are often carelessly exposed is probably the most dangerous aftereffect of all these accidents. As far as possible, keep the patient covered and warm during and after resuscitation. Use hot pads, hot water bottles, hot bricks, radiant heaters, or other similar means; but remember that an unconscious person has no way of telling you when he or she is being burned. Do not permit exertion on the part of the victim. If it should be necessary to move the victim, keep the person lying down.

**Exercises (093):**

1. In brief statements list the 5 steps in closed chest cardiac massage.

2. Where is the easiest place to detect a pulse on an individual?

3. If only one rescuer is available, what is the rate of compressions to one breath?

4. How long should you continue closed chest cardiac massage?

5. When giving closed chest cardiac massage to an individual, the rescuer exerts pressure at what rate?

6. What complication could result if you did not follow the correct procedure when performing closed chest cardiac massage?

7. Why is it necessary to keep the victim covered and warm during and after resuscitation?

**094. Identify particular blood vessels with their functions and procedures for controlling bleeding from lacerations and abrasions with their purpose.**

**Circulatory System.** In order to be able to stop or control bleeding, you must first understand something about how the blood circulates through the body. When blood leaves the heart, it is pumped into large vessels called arteries. As pressure from the heart drives the blood, it travels through small blood vessels called the capillaries. After leaving the capillaries, the blood starts its trip back to the heart. The blood enters larger and lager vessels, called veins. It is the veins that return the blood back to the heart.

**Types of Bleeding.** Types of bleeding are classified by the type of blood vessel which has been cut. These types are called capillary, venous, and arterial bleeding. In capillary bleeding, the blood oozes or flows at a very slow rate. The blood is bluish-red and is easily controlled. The rate bleeding will depend on the size of the vein that has been cut. The rate of flow will be more steady and darker in hue than capillary blood. In arterial bleeding, the most dangerous type, there is a large amount of bright red blood. It spurts in rhythm with the heart beat and can usually be detected by a pumping action. Of course, type of bleeding will influence the way you control the blood flow.

**Controlling the Blood Flow.** In attempting to control the flow of blood, there are a few steps that you should take immediately.

(1) Lay the victim down. If the victim does not lay down, faintness may occur at the sight of blood and further injury may occur.

(2) Expose the wound so that you can check the entire area affected by the cut.

(3) To stop the flow of blood you should apply pressure to the cut with a dressing or with some substitute such as an undershirt. Be sure to use a clean article if possible. Place the dressing against the cut and apply pressure. The pressure may be exerted by the use of the hand. Continue pressure as long as needed. If the cut is on the arms or legs, you may elevate the limb to help slow down the flow of blood. Do not raise the limb if you think the bone is broken. This could result in further injury. This procedure will usually control most severe bleeding of all types.

(4) If the above procedure does not work, you may be able to stop the flow of blood by applying hand or finger pressure at various points on the victim's body. The major pressure points are shown in figure 4-23. Each one of the dots in the figure is a major pressure point. The two most commonly used pressure points are the ones located in the groin and the inner side of the upper arm. Use the neck pressure point when the victim has a profusely bleeding scalp wound; however, use the neck pressure point only as a last resort—when all other methods of stopping the bleeding have failed. Do not apply pressure to both neck points at the same time. To do so would severely reduce the blood supply to the brain, causing unconsciousness and then death.

(5) If the bleeding has not been stopped by any of the steps so far listed, as a last step, use a tourniquet. A tourniquet could be defined as a wide band of cloth or some other similar material placed just above a wound to stop all flow of blood. Since the use of a tourniquet will stop all blood flow to the point of application, it should be used as a last resort only. Any time blood flow to a limb is stopped, you run the risk of losing that limb. As a last step, you may have to sacrifice a limb in order to save a life. Once a tourniquet is applied, you must insure that the victim receives care by a physician as soon as possible.

To use a tourniquet, place it just above the wound. If the wound is in a joint area or just below a joint, you should place the tourniquet right above the joint. Listed below are the steps to follow in applying a tourniquet.

*a*. Wrap the tourniquet band twice tightly around the limb and tie in a knot (see fig. 4-24,A).

*b*. Place a strong, short stick, or some similar object, on top of the knot. Tie two more knots on top of the stick (see fig. 4-24,B).

*c*. Twist the stick to tighten the tourniquet until the bleeding stops (see fig. 4-24,C).

*d*. Secure the stick in place with the loose ends of the tourniquet or another strip of cloth (see fig. 4-24,D).

*e*. Make a written note of the location of the tourniquet and the time it was applied. Attach this note to the victim's clothing.

*f*. Treat the victim for shock and also any other first aid he may require.

*g*. Never cover a tourniquet.

*h*. Do not loosen the tourniquet except on the advice of a physician.

Hopefully, you will never have to use any of these steps. But because of the dangers of your job, you could be in a

013 – 1. When an enemy knows in advance he is going to be attacked, he has time to plan his counteractions or avoid that attack.
013 – 2. The purpose is to keep the tactical and strategic advantage on our side by protecting information and activity regarding our plans.

014 – 1. (a) Identify those portions of an operation that require protection, (b) develop OPSEC procedures and techniques, (c) systematically assess OPSEC status at all operational levels, and (d) document deficiencies and institute corrective actions.
014 – 2. Operations, communications, and procedures.
014 – 3. Any type of information that could reflect a change in procedure or operations, whether the information seems important or unimportant.

015 – 1. a. Yes. This is a routine community relations effort, usually screened and cleared by the Office of Information.
b. No. This conversation deals with a probable limitation on a strategic weapon system component.
c. No. This conversation deals with the distances to the location of strategic weapons systems components from a known point.
d. Yes. This is a routine story for acknowledging excellence.
e. No. This also appears to be a probable compromise of classified material, since the "(S)" indicates Secret classification.
f. No. This information reveals a probable change in some part of the missile system, thus pointing toward other changes.

016 – 1. (1) a.
(2) b.
(3) c.
(4) a.
(5) b.
(6) c.
(7) a.
(8) b.
(9) c.
(10) a.
(11) c.
(12) c.

017 – 1. (1) a, b, d, h.
(2) c, e, f, g.
(3) b.
(4) c
(5) h.
(6) e.
(7) d.
(8) g.
(9) f.
(10) a.
(11) f.
(12) g.
(13) c.
(14) h.
(15) a.
(16) d.
(17) b.
(18) g.
(19) h.
(20) a.

018 – 1. (1) a, (2) b, (3) d, (4) c, (5) e, (6) a, (7) c, (8) e, (9) b, (10) d, (11) b, (12) a, (13) b, (14) e, (15) c, (16) d, (17) b.

019 – 1. They are identified by having the TO number placed on them and they should be dated. In some cases, a one-sheet identifying TO is issued as a title sheet.
019 – 2. They may be in the regular TO binders in numerical order with the other TOs or they may be filed in a separate file in numerical order. When in the regular TO file, the identifying title sheet is filed just in front of the publication. If kept in a separate file, the identifying title sheet is filed in numerical order and a notation in put on it to show where the publication is filed.
019 – 3. They are listed in the proper numerical index in numerical order.
019 – 4. (1) Some items are bought locally off the shelf and (2) some items are bought in very small quantities.
019 – 5. Specialized instructions, standards, and codes.
019 – 6. Through local procurement from the equipment manufacturer or from other commercial sources depending on the publication.
019 – 7. They are not indexed in the publications indexes but they should be kept together and filed in a section or on a shelf of a publications filing cabinet.

020 – 1. a. __, b. X, c. __, d. __, e. X, f. X, g. X, h. __, i. __, j. X.
020 – 2. a. F, they are issued as regulations; b. T; c. T; d. F, they are listed in numerical order; e. T; f. F, they are listed generally in the order they were issued; g. F, it contains only the general subject areas; h. T.
020 – 3. (1) g, (2) i, (3) f, (4) a, (5) b, (6) e, (7) b, (8) k, (9) f, (10) b, (11) k, (12) d.
020 – 4. In TO index 0–2–01 (NI&RT).
020 – 5. Electric drill press - category 34.
Oxygen cylinder - category 42.
020 – 6. Numerical index TOs begin with 0–1.
020 – 7. TO 0–2–1.
020 – 8. TOs are identified by category numbers and are indexed numerically, alphabetically, cross referenced, and by specific equipment.
020 – 9. 0–1–01.
020 – 10. The numbers of the first and last TOs in the binder are shown on a tab located on each binder.
020 – 11. TOs are filed in numerical order and, when alphabetical letters are involved, both numerically and alphabetically.

021 – 1. AFR 85–1, AFM 85–3, AFM 85–5, AFR 85–7, AFR 85–10, AFM 85–14.
021 – 2. AFP 85–1, AFR 85–9, AFM 85–13.

022 – 1. a. X.
b. ___.
c. ___.
d. X.
e. X.

023 – 1. (1) b.
(2) a.
(3) a.
(4) c.
(5) a.
(6) a.
(7) c.
(8) c.
(9) b.
(10) a.
(11) c.
(12) b.

024 – 1. Standard publications are filed in binders in numerical sequence by series number and specific item number. The binders are numbered and placed in the file in numerical sequence.
024 – 2. Changes are filed immediately behind the basic publication affected. Supplements are filed behind changes in descending order according to the level of command that published the supplement.
024 – 3. Binder 4.
024 – 4. Identify the number of the needed publication, check current status of the publication, and look at the binder inserts until you find the number on an insert or it falls between the numbers on an insert—your publication is in that binder.
024 – 5. First use TO 0–1–01 to find the proper category index number. Second, get the binder with the category index in it and look at the table of contents to find proper subcateogry for the type of tool you are looking up. Turn to the subcategory indicated and find the correct TO number. Then, look for the binder that contains the wanted TO, remove it from the file, and turn to the TO.
024 – 6. Binder 68.

025 − 1. Subjects in standard publications can be found in the table of contents or the index.
025 − 2. The index provides specific information whereas the table of contents contains general information.
025 − 3. (a) Locate the desired publication, (b) use the table of contents or the index and locate the wanted subject, (c) turn to the indicated page or paragraph, and (d) research the material for the desired information.

## CHAPTER 2

026 − 1. A work plan that identifies work ahead of time.
026 − 2. The planners perform an inspection of base facilities to find out what work needs to be done.
026 − 3. a. Recurring labor such as cathodic protection readings.
b. Equipment maintenance such as fire alarms.
026 − 4. Management by exception is the process of comparing estimated labor hours to actual labor hours.
026 − 5. Base Engineer Automated Management System (BEAMS).

026a − 1. To make uniform and accurate estimates for labor hours.
026a − 2. Industrial engineers and technicians.
026a − 3. Maintenance.
026a − 4. MTM is a system of predetermined standards for basic motion.
026a − 5. Time study.
026a − 6. Work sampling is a work measurement technique used primarily to determine percentage of work or delays as a part of the total time expanded.
026a − 7. Task-time standards show man-hours required to perform the work described and are used as a basis for information presented in the craft handbooks.
026a − 8. AFM 85 series.

027 − 1. A maintenance program that automatically schedules, through BEAMS, recurring work to the shops.
027 − 2. Shop supervisors will fill out an AF Form 1841, Maintenance Action Sheet (MAS) for each month.
027 − 3. Superintendents will review the RMPs to make sure only essential work is included.
027 − 4. Any of the following:
a. Calibrating thermostats on deep-fat fryers.
b. Maintaining emergency lights.
c. Reading static grounds.
d. Reading lightning protection.
e. Cathodic protection maintenance.
f. Fire alarm maintenance.
g. Intrusion alarm maintenance.

028 − 1. a. Uniform reporting system.
b. Identifies direct labor cost against work orders.
a. ATA.
b. ETA.

029 − 1. The controller or shop supervisor fills this form out on a daily basis to record man-hours used.
029 − 2. They are printed below the respective group, military or civilian.
029 − 3. The control center code and cost centercode.
029 − 4. The daily worksheet is based on AF Form 561.
029 − 5. A current job is assigned to that worker.
029 − 6. The man-hours are entered by numbers assigned to the jobs each person performs.

030 − 1. It is used to compute labor cost through BEAMS on a monthly basis.
030 − 2. Only labor loaned from ETA to ATA cost centers and family housing management.
030 − 3. Work control, planning, real estate management, cost accounting, engineering, and others like these.

031 − 1. a. An emergency work order from the service call desk.
b. A routine job order on AF Form 1879.
c. AF Form 327, BCE Work Order.
d. AF Form 1219, BCE Multi-Craft Job Order.
031 − 2. The shop supervisor.
031 − 3. The objective is to know the location of each workers and the status of all work.

032 − 1. (1) c.
(2) f.
(3) d.
(4) c.
(5) a.
(6) f.
(7) c.
(8) e.
(9) d.
(10) b.
(11) c.
(12) c.

033 − 1. Unit mission, number of people.
033 − 2. The table of allowance (TA).
033 − 3. The average AF unit.
033 − 4. TA–001 or MEMI.
033 − 5. 486.

034 − 1. The chief of supply.
034 − 2. To make sure all items are there and serviceable.
034 − 3. AF Form 126 is used to record all custodial requests.
034 − 4. The new custodian must attend the equipment custodian briefing and make sure all discrepancies are cleared up before signing for the account.
034 − 5. AF Form 601b is used to ask for allowance and authorization changes, ordering, turn-ins, and updating equipment.
034 − 6. TA–016.

035 − 1. Material Control.
035 − 2. Service call and your controller.
035 − 3. To make sure all items are there and correct.

036 − 1. Bench stock.
036 − 2. 30-day.
036 − 3. Material Control.
036 − 4. Bench stock code (always B).

037 − 1. (1) a.
(2) a.
(3) b.
(4) a.
(5) b.
(6) b.
(7) a.

038 − 1. Yellow.
038 − 2. Unserviceable but repairable.

039 − 1. AF Form 1801, Request for Issue or Turn-in, is used for expendable shop use type items.
039 − 2. The items are recurring issue.
039 − 3. The justification.

040 − 1. For temporary custody of an item.
040 − 2. Normally 24 hours, but does stay in effect until returned.
040 − 3. The form is returned to the individual.

041 − 1. All personnel.
041 − 2. TO 00–35D–54, USAF Material Deficiency Reporting System or AFR 66–30, Product Improvement Program for Operational Equipment.

## CHAPTER 3

042 − 1. a. To the mission.
b. Tell them the job comes first. As soon as the job is complete, they can have the time off.
042 − 2. Explain the situation to Sgt Sims and express regret in not being able to let him off at this time, because the mission must come first.
042 − 3. Explain to the colonel that you have a work schedule you have to go by and ask him to call the service call desk to get a work order.
042 − 4. Inform Material Control of the problem and turn them in for repair.
042 − 5. You will get the tools and equipment they will need, train them on shop tools and equipment, and provide on-the-job training necessary for upgrade training.

043 – 1. Job proficiency is knowing the 542X0 specialty principles and performing the skills.

043 – 2. a. Personnel probably would not respect you as a supervisor.
b. The product from your shop would probably be of marginal quality.

044 – 1. a. You explain to the worker that you are unfamiliar with that particular item of equipment but that you both can look it up in the TO or manual.
b. You make it known that your door is open to anyone that has a problem and wants to talk it over with you.

063 – 1. A CDC or STS training reference for the AFSC.
063 – 2. A person capable of administering job proficiency training.
063 – 3. The supervisor can certify job proficiency on the task if he or she observes the performance and can verify it by an authoritative reference (e.g., TO or manual)
063 – 4. Proper procedures, tools, materials, etc. are used and the completed work meets established standards.
063 – 5. The Chief, Personnel Division, must appoint a competent authority who possesses all the facts. This authority carefully weighs all factors to decide if a capability exists.
063 – 6. The Chief, Personnel Division, forwards a statement of circumstances to the parent major command (MAJCOM).
063 – 7. The MAJCOM.

064 – 1. a. Technological advancements.
b. Personnel changes.
c. Career field adjustments.
064 – 2. By applying a plan of evaluation
064 – 3. Current and projected training requirements.
064 – 4. Specialty description, STS, JPG and job breakdown, and the job performance requirements

065 – 1. How seriously the people in the program accept their responsibilities.
065 – 2. a. STS.
b. Current JPG.
c. Task breakdown.
d. Necessary tools, equipment, and supplies.
065 – 3. Trainee participation.
065 – 4. Written.
065 – 5. Performance.

066 – 1. a. Formal courses.
b. Career Development Courses.
066 – 2. a. Ability of recent graduates to perform tasks to the specified training standard.
b. Extent to which acquired skills are used by recent graduates.
c. Extent to which knowledge is retained by recent graduates.
d. Need to revise STS, formal courses or CDCs.
e. Need for further evaluation of training problem areas identified by this evaluation of recent graduates.

067 – 1. The official Air Force specification for training.
067 – 2. Tasks, knowledges, and study/technical references.
067 – 3. 3, 5, and 7 skill levels.
067 – 4. The career development channel of OJT.

068 – 1. g.
068 – 2. i
068 – 3. c.
068 – 4. m.
068 – 5. f.
068 – 6. n.
068 – 7. b.
068 – 8. j.
068 – 9. e.
068 – 10. l.
068 – 11. h.
068 – 12. a.
068 – 13. k.
068 – 14. d.

069 – 1. The Specialty Description in AFR 39–1.
069 – 2 To support task and knowledge training and as a basis for career knowledge training when CDCs are not available.
069 – 3. A proficiency code in these columns indicates the extent of training needed for the task in a course and/or OJT.
069 – 4 Through OJT.

070 – 1. The STS contains the majority of tasks for which an airman is responsible.
070 – 2 By drawing a circle around the proficiency code in columns 2A, 3A, or 4A.
070 – 3. By recording the date completed and the trainee and supervisor trainer initialing it.
070 – 4. Locally assigned tasks that are not on the STS.
070 – 5. Study technical reference, proficiency levels, and space for trainee's and supervisor's initials.

071 – 1. Circle and initial the appropriate verb.
071 – 2. The same as any task with only one verb.
071 – 3. The same as UGT
071 – 4. The supervisor must start the airman on a program of qualification training on that task.

072 – 1. If the JPG is not needed for recording 7-skill-level training, give it to the trainee. Otherwise, keep it for recording the UGT.
072 – 2. An airman who has dual qualification or one who is in retraining.
072 – 3. The supervisor must review each revised STS to determine if new JPGs are needed.
072 – 4 Erase the circle from the proficiency code.
072 – 5. Those applicable to the trainee's duty position.

073 – 1. For training documentation.
073 – 2. A comprehensive record of AFSC oriented training.
073 – 3. You should have an "X" by each of the following: b, d, e, f, and h.

074 – 1. At the lowest level of supervision having storage facilities.
074 – 2. To continue a filled section of AF Form 623.
074 – 3. If the airman is being separated or retired; also, upon an airman's promotion to E–7, provided it is not needed as an active training record.
074 – 4. In Section II when the trainee goes into UGT.
074 – 5. Record the date administered in column C, Section IV, AF Form 623.
074 – 6. 20 December 1978.
074 – 7. Estimated training completion date, date for supervisory evaluation, date for commander's evaluation, and the maximum training date.
074 – 8. a. I.
b. IV.
c. V.
d. V.
074 – 9. Place correction tape over the old entry. Enter the new information.

075 – 1. The immediate supervisor and the unit OJT manager.
075 – 2. To monitor the CDC progress of a trainee.
075 – 3. Once the CDC is successfully completed.
075 – 4. Upon issuance of the first volume for study.
075 – 5. The unit OJT manager.

076 – 1. Special task qualifications of a critical nature, selected tasks requiring training or evaluation, and tasks in which the supervisor relies on someone else to validate the individual's qualifications.
076 – 2. It saves the time it would take to screen entries on the JPG and AF Form 623a.
076 – 3. That the trainee must be administered both a written and practical evaluation for certification on that task.
076 – 4. The trainee must initial to indicate awareness and agreements with the applicable entries.
076 – 5. The trainee's grade and AFSC.
076 – 6. That the entry is noncurrent.

077 – 1. a. III.
b. V.
c. I.
d. IV
e. II.
077 – 2. To prepare airmen for noncommissioned officer status, and for positions of greater responsibility.

078 – 1. To motivate your trainees.
078 – 2. A goal.
078 – 3. The trainer's desire to teach.
078 – 4. By responding to the needs of the individual.
078 – 5. a. Success.
b. Self-esteem.
c. Security.
d. Enthusiasm.
e. Recognition.

## CHAPTER 4

079 − 1. That most accidents can be prevented before they happen.
079 − 2. To reduce accidents through the Air Force.
079 − 3. If unsafe conditions are not reported it could result in inefficient and costly operations.
079 − 4. To insure that corrective action is taken.

080 − 1. Safety orientations.
080 − 2. The supervisor.
080 − 3. a. X.
b. X.
c. X.
d. A safety briefing should be given on all phases of the worker's duties at least once a week.
e. X.
f. All jobs should be explained so the workers understand the proper procedures for doing the work.
g. X.

081 − 1. When your body is wet.
081 − 2. Current, 100 milliamperes (0.1 ampere).
081 − 3. Regard all circuits as being live until opened, tested, and grounded.
081 − 4. "X" items a, d, f, j.
081 − 5. Rubber gloves, rubber blankets, and rubber mats.
081 − 6. The circuit may become accidentally shorted to another circuit.

082 − 1. (1) b.
(2) c.
(3) a.
(4) d.
082 − 2. The office supervisor who issues an AF Form 269.
082 − 3. Not until the clearance, with the numbers corresponding to the numbers on all red and yellow tags on the blocked device, has been released.
082 − 4. The base civil engineer.
082 − 5. None; you are not required to work under conditions that you feel are unsafe.
082 − 6. Blocking is placing a switch in the OPEN or CLOSED position and providing a means to which the switch can't be accidentally changed.
082 − 7. To make sure unauthorized persons do not change the position of the switches.
082 − 8. The actual time each switching operation is performed.
082 − 9. Part A.

083 − 1. a. X. Use a screwdriver to drive and remove screws only.
b. ___ .
c. X. Store cutting tools with protective sheaths or store separate from other tools.
d. ___ .
e. X. Use a hammer to hammer a rusted pipe union.
f. ___ .
g. X. Keep the blades of screwdrivers ground flat and never use them as chisels.

084 − 1. a. U. Use three-wire extension cords with three-wire equipment cords and plug them into a grounded receptacle.
b.
c. U. Do NOT jerk the plug from a receptacle. Jerking the cord can break the cord wires or cause the connection in the plug to become loose and may cause a short circuit.
d. S.
e. U. Remove dust by ventilation before operating the motor or replace the motor with an explosion-proof type.
f. S.
g. U. Tools operated on 110 volts need one hot wire, one neutral (system ground) wire, and one equipment ground wire in their cords.
h. S.
i. S.
j. S.
k. S.

085 − 1. a. S.
b. U. All electrically operated machines will be grounded.
c. U. Use a brush to remove metal cuttings from machines.
d. S.
e. U. Do not perform maintenance on moving machinery.
f. S.
g. S.

086 − 1. a. S.
b. U - Get an assistant or a forklift.
c. U - You may lift the toolbox by yourself but bend your knees and keep your back straight.
d. U - Get an assistant or use a hoist.
086 − 2. c, d, b, a, e.

087 − 1. (1) c.
(2) b.
(3) a.
(4) b.

088 − 1. a. Yes.
b. Yes.
c. No. Extend an extension ladder after the ladder is against the structure.
d. Yes.
e. Yes.
088 − 2. Grasp the ladder by the rungs as you walk toward the bottom.

089 − 1. (1) e.
(2) d.
(3) g.
(4) f.
(5) b.
(6) a.
(7) c.

089a − 1. The goal of the hazardous material program is to prevent contaminating water supplies or the environment and protecting personnel.
089a − 2. Disposal may require hazardous waste to be reclaimed, burned, or buried.
089a − 3. Sewers, drains, on the ground.
089a − 4. a. Paint.
b. Solvent.
c. Oil.
d. Grease.
e. Detergent.
f. Acid.
g. Insulation compounds.
089a − 5. A liquid is covered by an absorbent material. A dry spill is covered with a plastic tarpaulin.

090 − 1. a. S.
b. U. The eyes must be immediately flushed and given medical aid in all cases.
c. U. Breathing the vapors may result in respiratory injury so ventilation is necessary.
d. S.
e. S.

091 − 1. (1) d.
(2) c.
(3) a.
(4) b.
091 − 2. Water, soda acid, and foam.
091 − 3. Foam $CO_2$, and dry chemicals.
091 − 4. Dry chemicals.

092 − 1. (1) Mouth-to-mouth.
(2) Mouth-to-nose.
(3) Back-pressure-armlift.
(4) Back-pressure-hiplift.
092 − 2. No, because it may flex the neck, causing the air passages to be blocked.
092 − 3. Provides rapid reoxygenation.
092 − 4. Air is being blown in the stomach instead of the lungs.
092 − 5. Until natural breathing is restored or until a physician declares the patient dead.
092 − 6. The victim may have a facial injury.
092 − 7. Back-pressure-armlift or back-pressure-hiplift.

092 – 8. Back-pressure-hiplift.

093 – 1. (1) Evaluate the situation.
(2) Position the victim.
(3) Clear the victim's throat and mouth of any foreign matter.
(4) Begin mouth-to-mouth resuscitation simultaneously with heart massage.
(5) Continue steps.

093 – 2. In the neck.

093 – 3. 15 to 2.

093 – 4. Until you get medical aid or until rigor mortus sets in.

093 – 5. Sixty times per minute.

093 – 6. Fractured ribs, injury to spleen, liver, or other organs.

093 – 7. To prevent pneumonia.

094 – 1. (1) c.
(2) a.
(3) b.

094 – 2. To help slow down the flow of blood.

094 – 3. (1) Groin.
(2) Inner side of the upper arm.

094 – 4. Applying a tourniquet.

094 – 5. A physician.

095 – 1. It may cause bleeding to resume.

095 – 2. If air is being sucked or blown out of the chest cavity, the air could squeeze and collapse the lung.

095 – 3. It could cause infection and severe shock.

095 – 4. Because of the many blood vessels in the neck area.

095 – 5. Exert pressure on the cut by applying a sterile dressing to the wound. Next bind the dressing to protect the wound. Have the person lie down. Treat for shock.

096 – 1. a. X.
b. Wet the victim down with a wet cloth but don't cool him too fast.
c. The body temperature will be normal.
d. X.
e. The victim should get a couple of days complete rest and stay away from excessive heat.
f. X.
g. X.
h. X.
i. The pupils will be dilated.

097 – 1. Shock is a condition of great weakness of the body.

097 – 2. By doing this you lessen the chances of the victim falling into a state of severe shock.

097 – 3. This will help to prevent choking, should the victim vomit.

097 – 4. To do so may cause the pressure to drop.

097 – 5. At the same time you start the first aid.

097 – 6. Any two of the following would be correct: loss of blood, crushed bones, bone fractures, burns, and bullet wounds.

097 – 7. Yes.

## CHANGES FOR THE TEXT: VOLUME 2

### Pen-and-Ink Changes:

| *Page-Col* | *Subject* | *Line(s)* | *Correction* |
|---|---|---|---|
| 45L | *Col B* | 5 | Add "m. Chain Wrench." |
| 71R | | 17 | Change "case, and" to "case, two." |
| 121L | | 6 | Change "(0ϕ)" to "(ϕ)." |
| | | 12, 18 | Change "30ϕ" to "3ϕ." |
| 150L | 255 - 11 | 1, 2 | Delete exercise. |
| 150R | | 15 fr bot | Change "231" to "256." |
| 169R | | 14 | Change "from" to "form." |
| 182R | | 14 fr bot | Change "0–000" to "0–1 |
| 198R | 241 - 13 | 12 fr bot | Change "21 - 13" to "241 - 13." |
| 199R | 246 - 4a | | Change "two 250" to "2250." |
| 201L | 255 - 11 | | Delete answer. |
| 202R | 263 - 5 | 3 | Change "field or at the" to "field or at the factory." |

### Page Changes:

| *Remove Pages* | *Insert Pages* |
|---|---|
| 27–28 | 27–28 |
| 115–116 | 115–116 |
| 193–196 | 193–196 |

The two ends of the loop are connected to sliprings. Two brushes ride on the sliprings. By rotating the loop, a current is generated. The current, in turn, is transferred by the brushes to an external circuit. You now have an elementary AC generator.

An AC generator and a DC generator, then, are identical in generating voltage by use of the rotating loop. If the current is taken from the loop by sliprings, it is an alternating current and the generator is called an AC generator. If the current is collected from a commutator, it is direct current and the generator is called a DC generator. You will find that AC generators are normally referred to as alternators.

**Exercises (211):**

1. What machinery supplies mechanical energy to a generator?

2. What is the primary difference between AC and DC generators?

3. How is a magnetic field established in a DC generator?

4. In what position is the rotating loop, in relation to the magnetic field, to produce a voltage?

5. What is used to deliver voltage from the commutator to the external circuit of a DC generator?

6. What type of generator uses sliprings and brushes to deliver voltage to the external circuit?

7. What type of generator uses a commutator to collect current from the rotating loop?

**212. Specify the characteristics and operation of single- and three-phase alternators.**

**Alternators.** Almost all of the alternators used in electrical power production by the Air Force are of the synchronous type with rotating fields and stationary armatures. With this type of construction, the fields are wound on rotor poles and the armature coils are assembled inside the alternator frame to form a stator assembly.

***Types of alternators.*** Generally speaking, alternators are of two types—single-phase and three-phase. They all look alike but are constructed differently. They operate on the principle of either moving conductors across a magnetic field or moving a magnetic field across the conductors. In either case, the results are the same. However, most of the AC alternators used in electrical power and production are designed so that the magnetic field is moved across the conductors. With this construction, the AC output is taken directly from the stationary stator coils. Thus, no brushes or sliprings are used in the alternator high voltage output, but they are used to feed relatively low DC to the rotor coils to produce the magnetic fields.

*Single-phase alternator.* A single-phase alternator is the simplest type. Notice the schematic wiring diagram of the single-phase alternator in figure 1-35. As shown by the sine wave in the diagram, the rotor revolves through one full revolution and produces one cycle of alternating current. The first half revolution of the rotor produces a voltage in one direction and completes the first half of the cycle; the second half revolution produces a voltage in the opposite direction and completes the last half of the cycle. This alternator will produce only one cycle of AC voltage during one revolution of the rotor. Since there are no overlapping cycles produced by the alternator, the voltage output is only single-phase.

*Three-phase alternator.* The output of the three-phase alternator can be used to operate virtually all electrical equipment at any Titan missile launch complex. For this reason, the three-phase alternator is most commonly used in electrical power production. While the output of this alternator is being used to operate three-phase equipment, any one of its phases can be used simultaneously to operate single-phase equipment.

Figure 1-36, a wiring diagram of the three-phase alternator shows the stator fields connected in pairs to produce a three-phase output. As the rotor turns through one revolution each phase produces one cycle. By

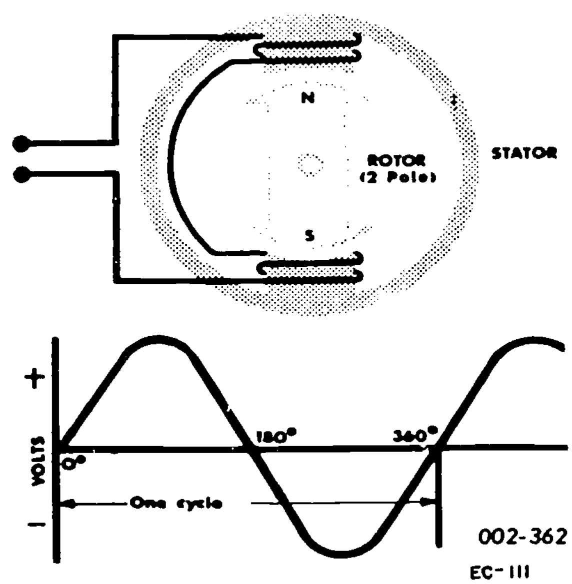


Figure 1–35. Schematic of a single-phase alternator.

overlapping the cycles, as shown by the sine wave, the three-phase alternator produces a three-phase voltage output.

In actual construction, the rotor pole windings of an AC alternator are electromagnets whose magnetic strength is controlled by the amount of DC voltage applied to the brushes and sliprings. An increase in DC voltage applied to the brushes and sliprings causes an increase in current through the rotor pole windings. This increase in current produces a stronger magnetic field and provides a greater AC output. On the other hand, when less DC voltage is applied to the rotor pole windings, the alternator will have a lower AC output.

To furnish electric current for exciting the rotor pole windings of an alternator, a source of direct current must be provided. This current is produced by an exciter. The exciter is a simple, direct current generator with a rotating armature and stationary field coils. The basic components of the exciter are the same as those for a generator.

As the rotor of a three-phase alternator revolves, each phase delivers voltage in a given sequence according to the method in which the alternator is connected. These phase voltages occur 120 electrical degrees apart. That is, when a cycle is started in a given direction by phase one, either phase two or phase three must start a cycle in the same direction 120 electrical degrees later. Also, a third cycle must be started in the same direction 120 electrical degrees after the start of the second cycle. The order in which these cycles are generated is called phase rotation.

**Alternator Output Connections.** You will find that there are two methods of connecting three-phase alternators. These are the DELTA and WYE methods.

*Delta connection*. With the delta connection, the three alternator phases are connected together as you see in figure 1-37. In this illustration, each coil of the delta represents one phase of the alternator. The voltage between any two lines is the same as the voltage of the coil between the lines

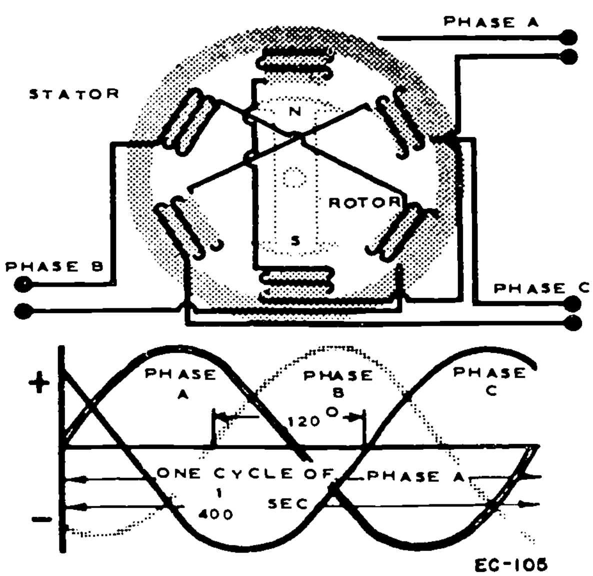


Figure 1–36. Schematic of a three-phase alternator.

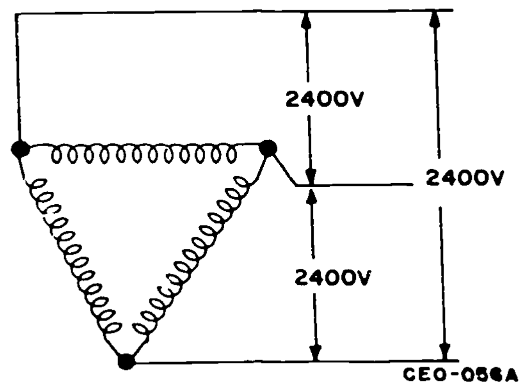


Figure 1–37. Delta connection.

(phase voltage). For example, if 2400 volts were generated in each phase of the alternator, the voltage between any pair of the three lines would also be 2400 volts.

*Wye connection*. With the wye-connected alternator, the phases are connected as shown in figure 1-38. In this type connection, the voltage between any phase line and neutral is equal to alternator phase voltage—2400 volts in this illustration. The voltage between any two of these phase lines, however, is approximately 4160 volts.

**Exercises (212):**

1. Why are most AC alternators designed with the magnetic field moving inside the stator coils?

2. How is DC voltage fed into the rotor coils?

3. How many revolutions must an alternator-rotor complete to produce one cycle of AC voltage?

4. How many revolutions must a three-phase alternator-rotor complete to produce three separate cycles of AC voltage?

5. How is the output voltage of an AC alternator controlled?

6. What is the purpose of an exciter on an AC alternator.

678

7. What is the purpose of phase rotation?

8. What alternator connections provide 2400 volts, phase to neutral?

**213. Distinguish between primary and secondary cells, and specify how storage batteries are constructed.**

**Batteries.** A battery is a device used to produce a voltage by chemical means. When such a source of voltage is connected to a closed circuit, chemical energy is changed to electrical energy. Other than generators, chemical action is the most common source of electrical energy. Today, most of us use batteries in some way. We start our cars and play our portable radios with the energy from a battery. We use batteries for emergency light and power, for alarm circuits, and for the operation of reays and other devices.

A true battery is made up of units called cells. The terms "cell" and "battery" are often used interchangeably. All cells are divided into two general types—primary and secondary. Once the primary cell is used up, it is useless. On the other hand, the secondary cell may be recharged. In

**245. Given a floor plan of a room with an electrical circuit shown, translate the information from the plan by drawing a working sketch to show how the circuit should be connected.**

As you have learned thus far, the information provided in the floor plan of a blueprint is limited to what circuits are to be installed, the devices that will be in the circuits, and where they are located. Circuit diagrams that show the actual wiring and the needed connections for the circuits are not provided with floor plans. Therefore, before you can start installing the circuits and components, you must be able to translate the information in the floor plan to a working sketch.

*Working sketch*. A working sketch is a drawing or sketch made by the electrician before starting the required work. It is drawn to help determine what size boxes will be needed, where connections will be required, and how the connections are color coded. It will be similar to the electrical diagrams discussed previously and will show as much detail as the electrician wants to use. Most of the time you will need to make a working sketch to help you in the installation of circuits. Here is an example of how it is done. Figure 5-5 is part of the floor plan of a house (in this case a bedroom). The symbols show that there is a home run (incoming power) to a lighting outlet in the ceiling, near the center of the room. It also shows that this lighting outlet is controlled by a switch just inside the door. The remaining symbols show a duplex receptacle outlet on each wall, the first one being fed from the ceiling outlet. The other outlets are then fed, in turn, off the first one. All circuit runs are shown as two conductors concealed in the wall or ceiling.

Now that we know what the floor plan shows, let's see what it does not show, and then take a look at a working sketch to see how it helps. First of all, the floor plan does not show the circuit connections or electrical operation as a schematic diagram would. There is nothing in the drawing that shows where splices might have to be made and, assuming the circuit to be wired with cable, there is no way to show color coding. Figure 5-6 is a working sketch of the floor plan shown in figure 5-5. Several things have been added to this sketch that you would not need to include in a sketch of your own. These are the dotted lines that represent boxes and the heavy lines and symbols taken from the floor plan. They have been included here simply to clear up a few points. The required equipment grounds have been left out to avoid confusion.

Your first step, if you were drawing the sketch, would to be to draw the symbols that represent all the devices that are to be in the circuit. They should be drawn in sequence, starting with the outlet that is connected to the home run. Notice that the ceiling outlet in figure 5-5 has the home run, a switch, and a receptacle outlet connected to it. It should be drawn so that it is nearest the power source in your drawing. The outlet will also serve as a junction box where splices in the wiring will be made. After the symbols are drawn, you should add the terminal connections that are required at each outlet. The sketch in figure 5-6 shows these terminals as S (silver) and G (gold) at the ceiling light and the receptacle outlets. The two terminals at the switch are not marked. The final step is to connect the wires and color code them. Start these connections at the power source. The floor plan shows two wires in the home run. One will be the hot (black) wire; the other, the neutral (white) wire. At the ceiling outlet, the hot wire will need to be spliced to provide power to the switch and to the gold terminal on the light. As you can see from the sketch, this hot wire loop (switch leg) has both a white and a black wire. The white wire goes from the splice to the switch. This is the only time that a hot wire can be white. This exception is allowed by the NEC when wiring with nonmetallic sheathed cable, because you are limited to the wire colors available in the cable. The neutral wire from the power source will also have to be spliced at the ceiling outlet to provide a neutral for both the light and the receptacles. The neutral is connected to the silver terminal of the light fixture and of all the receptacles.

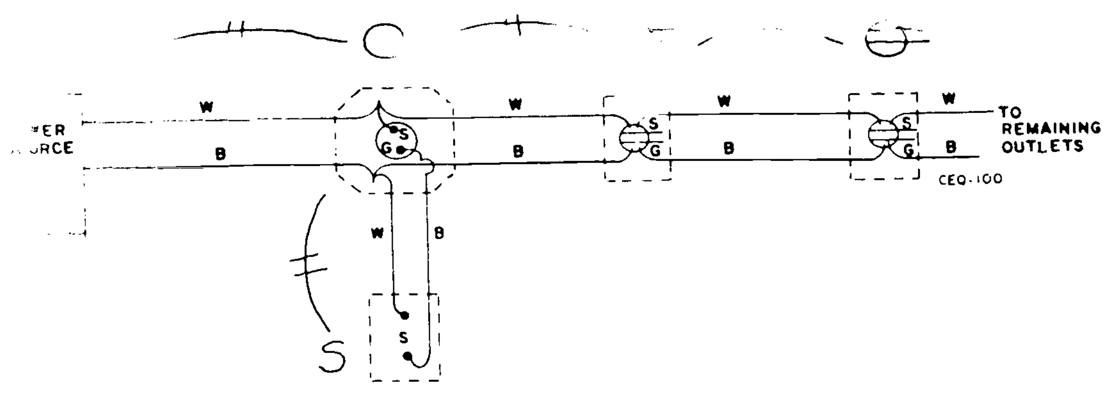


Figure 5-6. Working sketch.

**Exercises (245):**

1. Draw a working sketch of the circuit shown in figure 5-7. Show all necessary splices, terminal connections, and conductor identification.

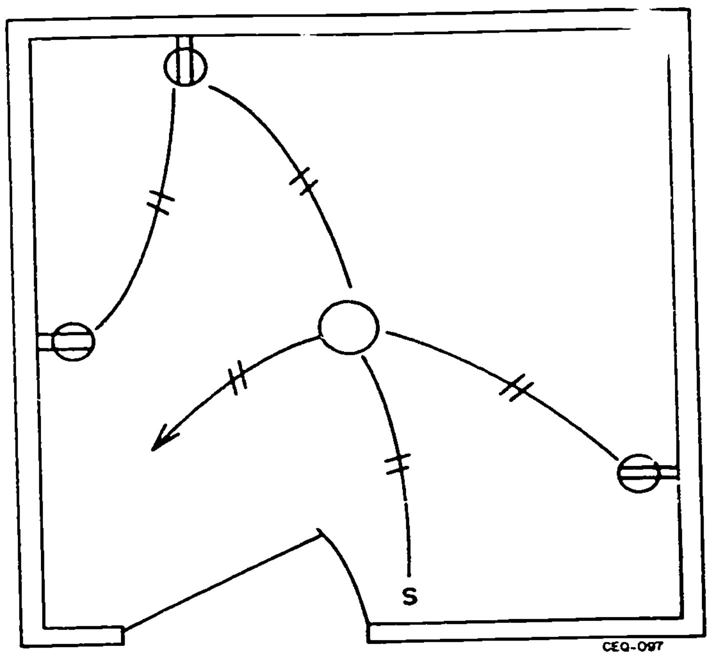


Figure 5–7. Floor plan (objective 245, exercise 1).

## 5-2. Calculating Power Requirements

Calculating a wiring system from beginning to end requires a broad knowledge of principles, tools, and techniques. Your main concern when calculating a wiring installation is safet Electr safety ers t ev ting fire and electric ' K. r b s cess in culating ectric using a proven standard of the nstructi in ry. The standard for electrical construction is the *National Electrical Code*, (NEC) sponsored by the National Fire Protection Association.

**246. Given a floor plan with an electrical drawing, calculate the power requirement of the circuits on the plan.**

**Calculating Residential Wiring.** To aid you in your study, foldouts 1 and 2 are provided at the end of the volume. Foldout 1 is an electrical floor plan of a single dwelling; foldout 2 is an electrical floor plan of an industrial location. Refer to the foldouts whenever necessary.

We begin our calculating lesson using foldout 1, single dwelling. The loads we will calculate are for general lighting circuits, special-purpose circuits, and the power requirements for the service equipment.

*General Lighting Load.* The general lighting load is computed on the watts-per-square-foot basis. NEC 220-2(b). "In determining load on the watts per square foot basis, outside dimensions of the building shall be used, not including open porches, garages, nor unfurnished and unused spaces unless adaptable for future use." m "unless adaptable for future use" means basemen tic areas that could be converted to bedrooms or recreation r s at a later time.

To find the square footage on foldout 1, multiply the length times the width, or 57 feet, the length of the back wall, times 28 feet, the width of the dining room and living room wall. The total is 1596 square feet. This is not our total figure. Look at foldout 1 closely. The measurement we made was a square that extended across the back wall and down the right hand wall. We cut across the open porch, through the closet and bedroom 1, and through bedroom 2. We need the remainder of the bedroom measurements and one additional measurement to complete the square foot calculation.

The left-hand wall, or outside wall of bedrooms 2 and 3, is 32 feet long. This is 4 feet longer than the right-hand wall of 28 feet. To figure this area, multiply 4 feet times the 27 feet along the front of the dwelling to the porch. The total is 108 square feet. We add this figure to our original figure of 1596 square feet, equaling 1704 feet overall. We are almost finished, only one more area to go.

Now we will calculate and subtract the open porch. Our first calculation used 4 feet of this area from the doorway out to the front edge of the living room wall. To find the width of the porch, add the two front walls, 27 feet plus 22 feet, equaling 49 feet. Subtracting 49 feet from the rear wall of 57 feet leaves 8 feet, or the width of the porch area. If we subtract the 32 square feet from our 1704 square feet overall, we find the total square footage for lighting on foldout1 at 1672 square feet.

NEC table 220-2(b), see figure 5-8, general lighting loads by occupancies, shows the unit load per square foot for dwellings is 3 watts. Foldout 1 has 167 Multiply 1672 by 3 watts, this equals 5, ts, our general lighting load.

NEC 220-3(d) "Watts per-sq e-foot load shall be apportioned evenly among bran circuits." To find the number of lighting branch circuits, divide 5,016 watts by 115 volts. This figures out at 43.6 amps. We will require three lighting circuits on foldout 1, 15 amps each, for an evenly distributed load.

*Minimum requirements for special purpose outlets.* We will now figure the minimum requirements for special outlets for a single dwelling.

*a.* NEC 220-3(c), requires a 20-amp, 1500 watt dedicated outlet in the laundry. You can see this outlet on foldout 1.

*b.* NEC 220-3(b)(2), requires two or more 20-amp small appliance branch circuits in the kitchen and dining room. You can see these outlets marked A and B oldout 1. Each circuit is required to have a 1500 watts capacity.

*c.* NEC 210-23, allows branch circuits to be installed for specific loads. On foldout 1 we have five branch circuits installed. A heater in each bath, a dryer in the laundry

**Exercises (273):**

1. When does a short exist?

2. When using an ohmmeter to check for a short, what does infinity reading mean after checking across two points?

3. What is indicated if, after you disconnect all equipment and install a new fuse, the fuse does not burn out?

4. During a visual inspection, what might be an indication of shorted wires?

# ANSWERS FOR EXERCISES

CHAPTER 1

**Reference:**

200 – 1. Elements are known as the building blocks of ..ature.
200 – 2. Matter is composed of very small units called molecules, which are made up of atoms, which in turn are made up of particles called protons, neutrons and electrons.
200 – 3. To water flowing through a pipe.
200 – 4. Water is composed of two distinct elements: two parts of the element hydrogen ($H_2$) and one part of the element oxygen (O), expressed $H_2O$.
200 – 5. Compounds can be separated only by chemical means, and a mixture can be separated by physical means.
200 – 6. A molecule.
200 – 7. Atoms.
200 – 8. Electrons moving or flowing through a conductor.

201 – 1. Voltage is electrical pressure.
201 – 2. Heat, magnetism, chemical action, and physical force.
201 – 3. Magnetism and heat.
201 – 4. By the cross-sectional area, the length, and temperature.
201 – 5. The ohm.

202 – 1. A natural magnet is a black mineral ore called lodestone or magnetite exhibiting magnetic properties. An artificial magnet is made of iron or steel magnetized by induction from some exterior object.
202 – 2. The lines connecting the direction of the field around a magnet from pole to pole are called lines of force.
202 – 3. It has an unstable physical structure and a low magnetic strength.
202 – 4. Hard steel or other substance that has the same characteristics. Hard steel will hold its magnetism for a long period of time.
202 – 5. In a north-south direction, aligning itself with the earth's magnetic field.
202 – 6. The field of stress interacts, causing repulsion or attraction, depending upon the polarity of the poles.

203 – 1. T.
203 – 2 F. All forces produced by magnetic circuits are called magnetomotive force. Electromotive force is the pressure needed to produce a flow of electrons.
203 – 3. T.
203 – 4. F. The lines of force are concentrated within the loop. The lines inside the loop combine as they come together.
203 – 5. T.

20 – 1. Electrons moving in one direction through a conductor.
– 2. Electrons moving back and forth through a conductor at a specific interval.

205 – 1. The relationship applies to any circuit or part of a circuit; the current in amperes is equal to the EMF in volts divided by resistance in ohms.
205 – 2.

a.

$$R = \frac{E}{I}, R = \frac{90}{30}, R = 3 \text{ ohms.}$$

b. $E = I \times R, E = 2 \times (7 + 5), E = 2 \times 12, E = 24$ volts

c.

$$I = \frac{E}{R}, I = \frac{24}{10 + 8 + 6}, I = \frac{24}{24}, I = 1 \text{ amp.}$$

205 – 3. In a series circuit, the relationship is as follows:

a. The total resistance is the sum of the individual resistors.
b. The same current flows in each part of the circuit.
c. The applied voltage will divide among the resistors according to their resistance.

206 – 1. The first step should be to reduce the two parallel resistors B and C to an equivalent single resistance.
206 – 2. In a parallel circuit, the total current equals the sum of the current in the branches.
206 – 3. The voltage drop would be computed by using the formula $E_s = I_T \times R_S$, thus $3 \times 10 = 30$ volts drop.
206 – 4. A series-parallel circuit should be reduced to an equivalent, simplified circuit. Each group of parallel resistors is first replaced by its equivalent single resistance, and the entire circuit is then treated as a series circuit.

207 – 1.
(1) d.
(2) b.
(3) a.
(4) c.
207 – 2. The power is computed with the formula $P = I^2R$.
207 – 3. 120 watts.

208 – 1. From negative to positive.
208 – 2. The term "hertz" has been adopted in recognition of Heinrich Rudolph Hertz, a German physicist.
208 – 3.
(1) i.
(2) a.
(3) k.
(4) b.
(5) e.
(6) h.
(7) d.
(8) f.
(9) c.
(10) c.
(11) j.
(12) l.

209 – 1. The current flow in a circuit containing resistance only is the same, regardless of whether the applied voltage is AC or DC.
209 – 2.
(1) c.
(2) a.
(3) b.
(4) e.
(5) d.

210 – 1. When the circuit consists of pure resistance.
210 – 2. When the current and voltage are out of phase due to reactance in the circuit.
210 – 3.

$$\text{Power factor} = \frac{\text{true power}}{\text{apparent power}}.$$

210 – 4. Pf = 90.47 or 90.5 percent.
210 – 5. Wattless power or reactive power expressed in VARs.

211 – 1. The prime mover.
211 – 2. The primary difference is the method by which the current is taken from the machine.
211 – 3. A set of coils acts as an electromagnet around the pole pieces to set up a magnetic field.
211 – 4. The rotating loop is at right angle to the field.
211 – 5. Fixed brushes make contact with the copper rings to conduct electricity to the external circuit.
211 – 6. AC generator.
211 – 7. DC generator.

212 – 1. The AC output is taken directly from the stationary stator coils. Thus, no brushes or sliprings are used in the alternator high-voltage output.
212 – 2. Through brushes and sliprings.
212 – 3. One revolution.
212 – 4. One revolution.
212 – 5. Output voltage is controlled by the amount of the DC voltage applied to the rotor pole windings.
212 – 6. An exciter is used to furnish electric current for exciting the rotor pole windings. It consists of a small DC generator.
212 – 7. The order in which phase voltages are produced in a 3-phase alternator. Regardless of placement, each phase must be 120 electrical degrees after the start of the previous phase.
212 – 8. The Wye connected alternator.

213 – 1. The primary cell can't be recharged; the secondary cell can.
213 – 2. The negative plate is spongy lead and the positive plate is lead peroxide.
213 – 3. Sulfuric acid and water solution.
213 – 4. Potassium hydroxide and distilled water.

214 – 1. 20 VAC.
214 – 2. Instrument transformers.
214 – 3. Step it up.
214 – 4. Buildup and collapse of the current.
214 – 5. Primary winding, secondary winding, and an iron core.
214 – 6. It may be center-tapped.

215 – 1. Transistors and vacuum tubes both conduct current in one direction easier than in the other direction.
215 – 2. There are three leads on a normal transistor. The center lead will always be the base lead.
215 – 3. When a high voltage gain is desired, the transistor is connected as a common base circuit.

216 – 1. The ordinary diode is a two-element, unilateral conductor and designed for current to flow through it in only one direction.
216 – 2. By an arrow printed on the side of the diode.
216 – 3. An SCR will conduct only if a voltage or current pulse is applied to the gate terminal. It will continue to conduct until its input voltage drops to zero or changes polarity, or its output voltage changes polarity.
216 – 4. In series.
216 – 5. A Zener diode conducts current in a forward direction at a very low voltage. In the reverse direction, no current will flow until the voltage impressed across it is equal to the Zener voltage.

217 – 1. T.
217 – 2. F. When the core is near saturation, it only requires a small change in the bias current to cause a large change in the load.
217 – 3. F. If the AC coil is the bias winding, then the saturation would be impossible to control over to the AC current changing directions.
217 – 4. T.
217 – 5. F. If the core is saturated, then the bias or control windings will not change the load current at all. To vary the amplifier, you need some room for adjustment.

## CHAPTER 2

218 – 1. (1) h.
(2) b.
(3) a.
(4) m.
(5) c.
(6) e.
(7) d.
(8) f.
(9) c.
(10) j.
(11) k.
(12) l.
(13) g.
(14) a.

219 – 1. (1) b.
(2) c.
(3) a.
(4) g.
(5) d.
(6) f.
(7) e.
(8) g.
(9) a.
(10) c.
(11) d
(12) b.
(13) d.
(14) f.
(15) b.
(16) b.
(17) c.
(18) d.
(19) f.
(20) g.
(21) g.
(22) e.
(23) d.
(24) b.

219 – 2. (1) f.
(2) d.
(3) e.
(4) a.
(5) b.
(6) c.

220 – 1. Fish tape. It is used to pull winch line or rope through first; then the winch line or rope is used to pull the conductors.
220 – 2. Folding rule.
220 – 3. By extending the metal slide at one end.
220 – 4. To measure the diameter of a wire to check the size.
220 – 5. To eliminate the danger of electric shock.
220 – 6. Reamer.
220 – 7. Make sure the size of wire being stripped is not larger than the slot. If you don't, the wire may be nicked or cut.

221 – 1. Electric and nonelectric.
221 – 2. Propane.
221 – 3. Soldering copper.
221 – 4. In watts.
221 – 5. To absorb heat and protect components.

222 – 1. Lead and tin.
222 – 2. The solder contains 60 percent lead and 40 percent tin.
222 – 3. Rosin flux.
222 – 4. It must be tinned.
222 – 5. Clean with a rosin flux.
222 – 6. From under the splice or joint.
222 – 7. Make sure enough heat is used.

223 – 1. T.
223 – 2. F. By a key-type gear check.
223 – 3. T.
223 – 4. F. The spade bit does not have a screw tip; therefore, pressure must be applied.
223 – 5. F. You must reduce the pressure or the bit will splinter the wood.
223 – 6. T.
223 – 7. T.
223 – 8. T.
223 – 9. F. Several types of blades are made for the saber saw to cut different types of material.
223 – 10. T.
223 – 11. F. Always apply steady, even pressure and hold the base plate firmly against the work.

## CHAPTER 3

224 – 1. A thin rod of hard or soft drawn metal that conducts easily, such as copper or aluminum.

224 – 2. A bare or insulated wire or group of wires [illegible] insulated from each other, which is suitable for carrying current.
224 – 3. A solid conductor is a single wire; a stranded conductor is a group of single wires twisted together.
224 – 4. Copper.
224 – 5. No. 40, the smallest, to No. 4/0, the largest.
224 – 6. No. [illegible] AWG.
224 – 7. They are sized according to cross-sectional area and [illegible] to circular mils.
224 – 8. For flexibility.
224 – 9. a. TA-Thermoplastic and asbestos
b. RH-Heat [illegible] rubber.
c. [illegible]HW-Moisture and heat-resistant thermoplastic
224 – 10 Conductors in conduit will not get rid of heat as fast as those in free air.

225 – 1. To reduce the possibility of fire; to provide physical protection for wire terminals, splices, and electrical devices; and to protect people from accident shock, burns, or possible electrocution.
225 – 2. Outlet boxes and junction boxes.
225 – 3. Another outlet box is used to mount a switch, receptacle outlet, or lighting fixture, while a junction box is used to inclose connections or splices between conductors.
225 – 4. a. T.
b. T.
c. T.
d. F.
F.
225 – 5. Handy.
225 – 6. Metal and insulating material.
225 – 7. Boxes are galvanized, enameled, or coated with other corrosion-resistant material.
225 – 8. With nonmetallic wiring methods, such as nonmetallic sheathed cable or rigid nonmetallic conduit.
225 – 9. A prepunched disk that can be knocked out easily so that conduit or cable connectors can be installed.
225 – 10. A prepunched slotted piece, that can be twisted out with a screwdriver. They are punched in boxes with built-in cable clamps.
225 – 11.(1) e.
(2) d.
(3) e.
(4) b.
(5) c.
(6) d.
(7) e.
225 – 12. By use of a fixture stud.
225 – 13. Conduit can be connected to the sides of the boxes as well as to the back.
225 – 14. A pull box is used to allow conductors to be pulled through conduit to an intermediate point in the circuit and then to the end point without having to be cut and spliced.

225 – 15. A square box.
225 – 16. Ganging means to remove one side from two device boxes and then fasten them together by means of the side retaining screws to form a large box to mount two devices side by side.
225 – 17. They may be used as junction boxes or for switches or receptacles in concealed wiring.

225 – 18. A round box.
225 – 19. An extension ring looks similar to a box without a closed back. It has a narrow flange that provides a seat for mounting the extension to a box.
225 – 20. To increase box capacity, to bring the edge of a box out flush with the wall surface when a box has been mounted too deep, and to extend the edge of an old box beyond the surface of a wall to permit the addition of surface wiring.
2[illegible] 21. By using rings designed to extend existing boxes flush to the new wall. They are held in place by long screws run through the devices and rings and screwed into the original box mounting holes.

226 – 1. T.
[illegible] 2. F.
226 – 3. T.
226 – 4. T.
226 – 5. T.
226 – 6. T.
226 – 7. T.
226 – 8. T.
226 – 9. F.

227 – 1. (1) a.
(2) h.
(3) b.
(4) c.
(5) d.
(6) e.
(7) e.
(8) j.
(9) f.
(10) g.

228 – 1. To conduct and disconnect electrical circuits or components from the power source.
228 – 2. Two three-way switches.
228 – 3. Two three-way switches and one or more 4-way switches, depending on the number of switching locations required.
228 – 4. Three.
228 – 5. In a switchbox with the toggle pointed up when the switch is on and covered with a switchplate.
228 – 6. Switches are rated according to voltage and amperage capacities.
228 – 7. Four.
228 – 8. All conductors at the same time.
228 – 9. SWD.
228 – 10. 6½ feet.

229 – 1. A receptacle is a contact device installed at the outlet box for connecting and disconnecting appliances, tools, etc.
229 – 2. Attachment plug.
229 – 3. A heavy-duty receptacle is ordered for a specific voltage, amperage, and number of contact pins required.
229 – 4. (1) b.
(2) d.
(3) c.
(4) a.
(5) e.
(6) e.

230 – 1. Light fixtures are classified according to the way they distribute light.
230 – 2. Direct, semidirect, general diffuse, semi-indirect, and indirect.
230 – 3. 10-40 percent.
230 – 4. 10-40 percent.
230 – 5. Indirect.
230 – 6. Indirect.

231 – 1. The incandescent lamp.
231 – 2. The incandescent lamp.
231 – 3. Mogul socket.
231 – 4. The medium socket.
231 – 5. The candelabra and intermediate sockets.
231 – 6. At least an 80-watt incandescent lamp.

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## CHANGES FOR THE TEXT: VOLUME 3

### Pen-and-Ink Changes:

| *Page-Col* | *Subject* | *Line(s)* | *Correction* |
|---|---|---|---|
| 53R | | 12 fr bot | Change "ror" to "for." |
| 62R | | 20 | Change "change" to "charge." |
| 113L | | 13 | Change "mat" to "map." |
| 113R | | 14 | Change "Before the" to "Before any pipeline." |
| 116L | | 13 fr bot | Delete "measure." |
| 136R | | 12 fr bot | Change "3159-4" to "31S9-4." |
| 137L | | 6 fr bot | Change "3159-4" to "32S9-4." |
| 137R | | 23 | Change "3159-4" to "32S9-4." |
| 143L | 459 - 6 | | Delete "not." |
| 153L | | 9 | Change "data identification number (DIN)" to "DIN." |
| 158R | | 15 | Change "if" to "If." |
| 173R | 455 - 7 | | Change "3159-4" to "31S9-4." |
| | 456 - 2 | | Change "315-4" to "31S9-4." |

### Page Changes:

| *Remove Pages* | *Insert Pages* |
|---|---|
| 119–120 | 119–120 |
| 159–162 | 159–162 |
| 173–174 | 173–175 |

686

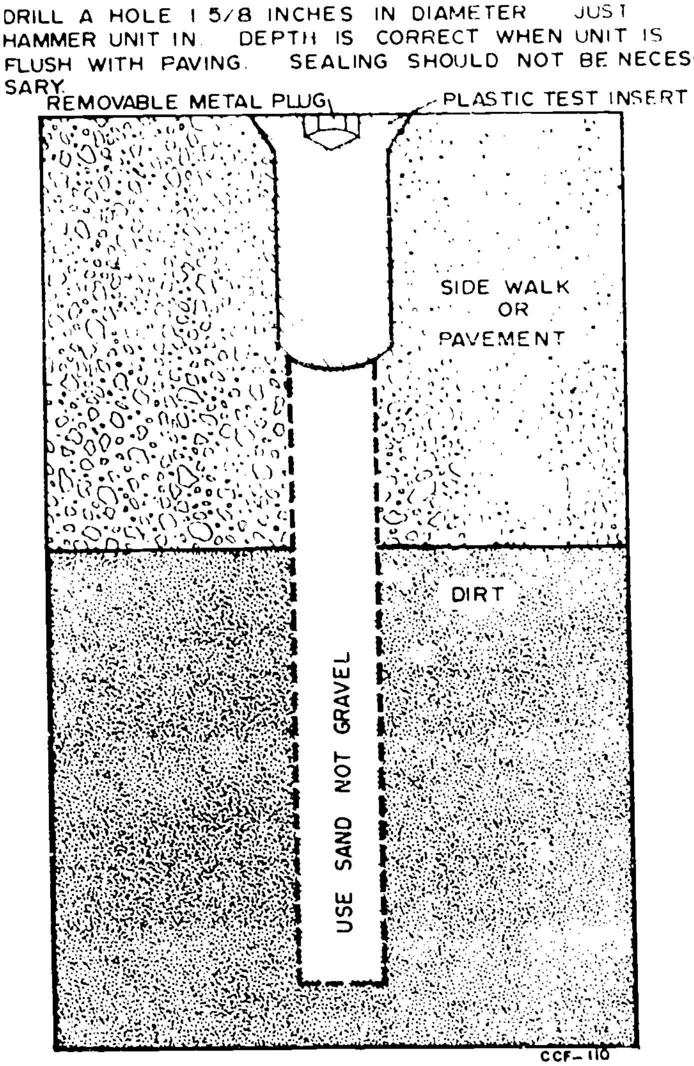


Figure 4-19. Plastic test insert.

two types of stations may be installed for potential-only or potential-current measurements. Since the use of the test stations usually requires making a physical disconnection between the anode and the structure, it is extremely important to insure that the connection is properly restored at the completion of the testing. Where shorting lugs are used, be sure that the nuts or screws holding the lugs in place are firmly snugged down and that a good metal-to-metal contact is made. Where galvanic anodes are involved, test leads should be terminated on terminals.

Since cathodic protection systems are electrical in nature, it is important that the current be allowed to flow where it is needed without unnecessary loss or restriction. The two usual causes of loss and restriction are high-resistance connections and poorly insulated connections. Connections to the structure will be thermite welded or brazed and then insulated from the electrolyte. Conductor splicing should be avoided where possible. Permanent conductor splices will be done by thermite welding or crimped pressure connection with proper ratchet tools.

The simplest and best method of attaching leads to structures and obtaining a good electrical connection is the thermite welding process. Thermite welding is a means of permanently fastening copper conductors to steel or iron structures or to another copper conductor. Powdered copper oxide and aluminum are burned to provide heat and molten copper. The molten copper flows over the conductor and the structure, permanently welding them together. The equipment is light and portable, and no outside source of heat or power is required. The thermite weld furnace must be of the proper size for the pipe and wire size encountered. Underground splices are adequately insulated by three wraps of insulating electrical tape.

The completed thermite weld and exposed copper wire must be coated with a thermite weld cap filled with mastic. The cap must not be installed until after the weld has cooled sufficiently to prevent mastic from melting or burning.

**Exercises (447):**

1. What two purposes do electrical measurements serve in a cathodic protection system?

2. When should a record of structure-to-soil measurements be initiated?

3. Which is the most important measurement made in cathodic protection?

4. What two test instruments are used to measure cathodic protection?

5. How are the meters listed in the preceding question connected?

6. What indicates whether or not the structure is adequately protected?

7. What do sudden changes in potential indicate?

8. What could give you an erroneous reading when taking structure-to-electrolyte potential readings?

9. What will an anode-to-electrolyte potential indicate?

10. How is an anode-to-structure current measurement made?

11. What is the most efficient method of measuring structure-to-electrolyte potentials under pavement?

12. How can a leak in a pipeline system be detected without excavating the pipe?

13. What is provided in the cathodic protection system to make the electrical measurements more convenient?

14. What are the two methods of attaching conductors to the structure?

15. How are the underground thermite welds insulated from the electrolyte?

**448. Describe the procedures used to perform resistivity tests.**

**Resistivity.** The ability of soil or water to conduct electricity is closely related to the rate at which buried or immersed structures will corrode. The lower the resistance to current flow, the higher the rate of corrosion. The practical measure of the ability of a material to resist the flow of electricity is known as resistivity. Resistivity is defined as the resistance in ohms between opposite faces of a 1-centimeter cube of material. The basic circuit for the measurement of soil resistivity is shown in figure 4-20. While resistivity measurements can be made using a voltmeter and ammeter as shown, most resistivity measurements are made using the Vibroground instrument.

*Soil resistivity.* Soil resistivity is found by measuring the current flow through a specified section of earth, determining the voltage drop across all or part of the earth under test and using these measured values to calculate the resistivity by formula. Figure 4-20 shows the basic circuit used for this determination. The resistivity (P) is calculated from the formula:

$$(RHO)\ P = \frac{191\ AP}{I}$$

Or

$$P = 191\ AR$$

Where

A = pin spacing in feet

R = instrument reading in ohms

The formula may be further simplified to:

$$P = KR$$

Where

$$K = 191A$$

If the soil pins are spaced as shown in table 4-5, the soil resistivity is simply calculated by multiplying the instrument reading by K from the table. A commonly used pin spacing is 5 feet so that K = 1000. This calculation will give the average soil resistivity down to a depth about equal to the pin spacing. By changing the pin spacing, the resistivity to other depths can be determined.

Polarization and galvanic effects between the electrodes may cause errors in the calculated resistivity when only one DC measurement is made. These effects may be eliminated by reversing the DC current and averaging the results or by using an AC current and AC measuring equipment. Earth resistivity meters use alternating current for this reason. Figure 4-21 shows how the instrument is connected to the field soil probes or pins. The Vibroground instrument reads directly in ohms.

*Water resistivity.* Water resistivity is usually determined by calculation from its inverse characteristic, conductivity. Conductivity is the ability of a material to conduct electricity and is numerically equal to the reciprocal of the resistivity. The basic unit of conductivity is ohms per centimeter, but most water analyses report conductivity in millionths of ohms (or micro ohms) per centimeter. The conductivity of every domestic water supply used by the Air Force is reported as a part of the annual water analysis by the U.S. Geological Survey for CONUS installations and some overseas installations.

Limitations of the 4-pin method can be overcome by using the single rod probe method or by measuring the resistivity in the soil box. The single rod probe measures the soil resistance between two electrodes on a single probe. It will measure the local soil resistivity in the immediate vicinity of the tip of the probe placed into the soil or liquid. It is useful for obtaining resistivities of liquids or soil resistivities in excavations and trenches. Similarly, the soil box method measures the resistivity of a small sample of electrolyte. This method of obtaining soil resistivity is a modification of the 4-pin method applied to small samples

**Broken Fan Belt.** A substitute fan belt can be made from a small rope or from a strand of a larger one. Loosen the generator and apply the rope; tie the ends with a square knot. Then tighten the generator and trim the knot. If sufficient adjustment is available, the ends of the broken belt may be wired together as a temporary repair.

**Cracked or Broken Fuel or Oil Line.** Break the line and install a piece of hose (from the windshield wiper or air horn) over the ends. If this makes the wiper hose too short, plug the opening to the engine with a wood plug. Another temporary repair can be made with a tight wrapping of tape or other nonporous material secured with closely wrapped wire or string.

**Wet Ignition System.** Wet distribution and ignition system components may be dried by wiping them off with a clean dry cloth.

**Vehicle Jump Starts.** Follow the procedures described below in making jump starts:

*a.* Make sure that both the "live" and the "dead" batteries have the same rated voltage and the same type of electrical ground systems. Check this by looking at the battery terminals. The terminal marked "-", "N", "NEG", or "negative" should have a wire running to the car's frame or engine block.

*b.* Make sure that the "dead" battery isn't frozen. Electrical current from a live battery could cause the dead one to explode, either from too much pressure or from a hydrogen gas detonation. If you're not sure whether the dead battery is frozen or not, our advice is don't try to jump start.

*c.* Bring both vehicles close together but not touching; you may cause sparks or short circuit the good battery if they touch during the jump start.

*d.* Keep the "booster" vehicle engine running, turn off all accessory switches in the "dead" vehicle, set both parking brakes, and don't stand between the two vehicles.

*e.* Remove the well caps from both batteries to provide adequate ventilation for hydrogen gas generated by the battery; cover the wells of each battery with two layers of cloth. (This provides better dissipation of the hydrogen gas and minimizes danger from sparks.)

*f.* Find the "positive" terminal of both batteries. This will be marked on or near the terminal post with either a "P," "POS," "Positive," or a "+" mark. Connect one cable clip to the positive terminal of the live battery and the other clip on the same cable to the positive terminal of the dead battery.

*g.* Connect one clip to the live battery's negative terminal and the other end of the cable to the frame of the "dead" vehicle as far from the battery as cable stretch will allow. This will help prevent any sparks from igniting the hydrogen gas.

*h.* Start the "dead" car's engine and disconnect the two cables in reverse order. Remove cloths from well holes and replace vent caps. Aluminum cables get very hot during a jump start, so allow time for them to cool before putting them away.

**Exercises (467):**

1. State the proper procedures for making emergency repairs for the following:

   a. Broken hydraulic brake line.

   b. Punctured gas tank.

   c. Broken fan belt.

   d. Vapor lock.

   e. Broken fuel line.

   f. Wet ignition.

2. When jump-starting two vehicles, why shouldn't vehicles touch?

3. Why should the negative side of jumper cables be as far away from the battery as the cable will allow?

4. After the "dead" car's engine starts (during a jump start), how must the battery cables be disconnected?

**468. State precautions and requirements for operating the aerial bucket truck and identify particular controls with locations and functions.**

**Operator Safety.** Because of the advanced hydraulic design and built-in safety features of today's bucket trucks, very little training or skill is needed to safely operate these trucks. However, any truck used to lift personnel is dangerous in the hands of careless or untrained operators. Even after training, in many cases, an operator has admitted being aware that the booms or some part of the truck were not operating properly. If,

when operating the boom, you sense anything different, such as hearing noises or feeling unusual movement, STOP at once and resolve the problem. This one simple and basic caution, if heeded, could have prevented many of the most serious bucket truck accidents. It is strongly recommended that you and all bucket truck operators follow these simple rules for safe operation and reduction of "downtime" from damaged equipment:

*a.* Allow only qualified operators to operate the controls.

*b.* Operators must be thoroughly acquainted with the operating instructions and limitations of the bucket truck.

*c.* Lubricate and inspect the truck and attached equipment at regular intervals.

*d.* Allow repairs and adjustments to be made only by qualified personnel.

*e.* Do not exceed personnel basket weight limitation.

*f.* Set truck's parking brakes before operating booms.

*g.* Check the complete truck and attached equipment for visible defects or loose objects.

*h.* Check insulated boom for cleanliness and moisture before operating it near energized lines.

*i.* Do not operate boom unless truck is on solid ground and outriggers are extended properly.

*j.* Be sure outrigger lock valves are closed while operating the boom.

*k.* Operate all controls slowly for smooth bucket movements.

*l.* Always use safety belts when operating the bucket.

*m.* Try to avoid maximum outward extension of the booms.

*n.* Do not allow the bucket to come in contact with a fixed object; set in cradle only.

The preceding material represents some basic safety rules that all operators should follow for maximum safe operation of the bucket truck. Remember that your truck cannot protect or service itself. It is up to the operators to insure that the truck stays in good condition.

**Setting Up the Truck.** Position the truck so that the working area is within the reach of the booms. If the truck is positioned on a sloping surface, locate the work to avoid extending the booms to their maximum reach on the downhill side.

Once the truck is in position, operators perform the following steps:

(1) Engage the emergency brake.

(2) Engage power take-off in accordance with the operation and maintenance manual.

(3) Open the shutoff valves for outriggers located at the rear of the truck.

(4) Hold control handle in the down position and lower the outriggers far enough to raise the truck body (not rear tires) 2 inches.

(5) After all outriggers are firmly in place, close all shutoff valves.

(6) Unlatch the upper boom holddown device and remove the band; then pull the locking pin holding the lower boom. (The booms of the truck are now ready for use.)

**Operation of the Aerial Basket.** The operator should mount the basket and put on the safety belt while insuring that the rider does the same. To operate the booms, you must press the trigger on the underside of the control head handgrip. If you move the control head handle horizontally (backwards and forward), this will cause movement of the lower boom; forward to raise, backward to lower. If you move the handle vertically (up and down), this will cause movement of the upper boom: up to raise, down to lower. Rotation of the handgrip will cause rotation of the turntable. Any combination of these movements may be used at the same time to direct basket movement to any point. No movement will result from actuation of the control handle unless the trigger is depressed.

CAUTION: When operating the aerial basket, follow these simple rules:

(1) Always press the trigger on the handgrip before you move the control handle.

(2) Return the control handle to the neutral position before you release the trigger on the handgrip.

(3) Avoid sudden stops or reversal of rotation when turning. (This will prevent stress on the turntable which may cause damage and become a safety hazard to the personnel in the basket.)

(4) Before any rotation of the booms (left or right), raise the lower boom at least 2 feet above its cradle.

**Auxiliary (Secondary) Control.** Three hand-control levers are found on the main hydraulic control valve, near the base of the lower boom. These three levers control the operation of all the basket movements from the ground. No movement of the booms will result from actuation of the levers unless you have depressed the auxiliary palm switch on the turntable or the trigger in the control head handle.

**Folding for Travel.** The booms of the truck must be completely seated in their cradles with no tension remaining on the main boom lifting cable. Always make sure that the upper boom holddown device and the lower boom locking pin are in place before truck movement. If the booms are allowed to bounce in the cradles, the insulated plastic becomes crazed and shattered, eventually allowing the boom to buckle.

In the event of engine or hydraulic system failure, the aerial basket may be returned to the ground level by following the special procedures outlined in the operation and maintenance manual. Never allow anyone to slide down the boom or descend by the use of a handline.

**Vehicle Storage.** If the bucket truck is stored outdoors, you must protect the basket from the weather with a waterproof canvas cover when the basket is not in use. Remember, this basket serves to help insulate the operator from energized electrical circuits and the ground. Take good care of it.

**Exercises (468):**

1. What precautions should be observed when the bucket truck is positioned on a sloping surface?

2. What movement develops when the control head handle is moved forward with the trigger depressed?

3. List five safety precautions you should follow when operating the bucket truck.

4. Who is allowed to operate the bucket truck in the Air Force?

5. Where are the auxiliary controls located?

**469. Clarify particular purposes, precautions, and operations relating to the line maintenance truck.**

**Line Truck.** The line truck is used for construction and maintenance of electrical distribution lines. Most line trucks have a compartmental body, a power-driven winch, capstan, tow hooks, a boom, and body support jacks.

*Compartments.* There are bins on the line truck for your tools, equipment, and materials. Keep each item in its place. You should carry at least a 1-day supply of hardware, such as bolts, lag screws, connectors, and tape. The equipment needed for electric line work will also be stored on the line truck.

*Power-driven winch.* The winch is operated through the truck power takeoff. Most line trucks have two winch drums. One is located in front and the other is tied in with the boom operation. Both winch drums have automatic brakes which prevent them from turning under a load except when the truck engine is running. Do not exceed the load limitations of the truck and winch line. The manufacturer provides a load capacity chart. The winch will safely lift 15,000 pounds with the cable on bare drum wrap layer and 6,000 pounds with a full drum. For loads that are less than 10,000 pounds, 1/2-inch wire rope will be sufficient. When lifting loading over 10,000 pounds, use 5/8 IWRC 6 x 19 VHS cable. Avoid stacking the winch line and jerking the load.

*Boom.* The boom and winch are used to raise the set, pull and lower poles; load and unload poles from the pole trailer; and load, unload, raise, or lower pole line equipment such as transformers. Read and understand all operating instructions before you operate the boom or any other part of the truck. The operation of the line truck can be extremely hazardous if you don't know what you are doing. All winch and bom operations must have at least two persons—an operator and a spotter who give signals.

Position the truck to work on the high side when parked on a crown or slope. Avoid soft ground and overhead obstructions. Set the parking brake. To engage the power takeoff (PTO) with standard transmission, push in the clutch, place in neutral, engage the PTO, and release the clutch. To engage the PTO if your truck has a transfer case, push in the clutch, put the transfer case in neutral, and engage the PTO. Put transmission in fourth gear and let out the clutch.

Never operate the boom without the jacks down. The jacks are lowered until the tires are almost off the ground. The truck bed is leveled by raising the high side jacks. Level the truck to within 15-percent grade (8½°) for lifting to prevent boom side overload. If there is a question about soft ground, hot asphalt, or weak pavement, then use planks of sufficient area and strength under the jack pads. Some trucks are equipped with a safety switch that prevents boom operation if the jacks are not all the way down. Check the operator's manual for override procedures if they become necessary.

Observe the following precautions when operating the boom:

- Do not operate the boom when winds exceed 30 mph (26 knots).
- Do not operate steel booms within 15 feet of energized overhead lines.
- Do not pull poles out of ground with derrick booms.
- Do not pull side loads with the boom.
- When dragging poles, line up boom with winch cable.
- Do not pull stumps with boom and winch (use a pole jack).
- Do not rock pole with boom to loosen it in the hole.

*Capstan.* The capstan is used for raising loads like transformers, pulling slack in conductors, or holding a strain. LWind the rope on the capstan in a clockwise direction, as shown in figure 7-16, with the load end next to the truck. Keep the direction of the load at a 90° angle to the capstan so the rope will not climb the flange or bind at the burns. Vary the number of turns of rope from three to six or more, depending on the weight of the load.

The capstan turns clockwise to raise a load, and it stops for lowering heavy loads. To pick up a load, gradually increase the strain on the free end of the rope until the load is being reeled in at the desired rate. Lessen the strain to slow or stop the load pickup.

Always keep the free end of the rope in the clear. Do not stand on the free end or allow it to tangle around your feet. A wet rope sticks, slips, or binds and makes lowering or holding a load difficult. An oily rope slips too fast, allowing a load to lower too fast.

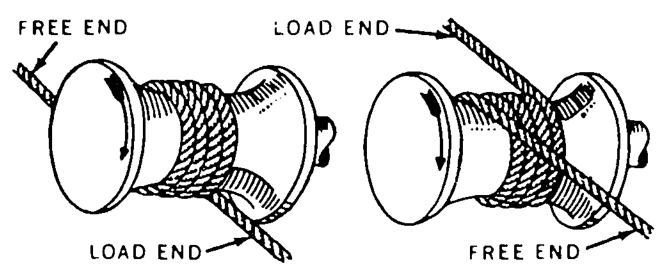


Figure 7-16. Capstan.

**Exercises (469):**

1. Name three items of equipment found on the line truck used for construction and maintenance.

2. How is the power supplied to operate the line truck winch and boom?

3. How is the winch drum prevented from turning under a load?

4. The boom will not be operated when winds exceed ____________ miles per hour.

5. What is the purpose of the capstan?

**469a. (475—for CE feedback reference only). Cite characteristics and operating procedures of forklits.**

**Forklifts.** On most forklifts, the lifting and tilting action of the forks is powered by a hydraulic pressure system. This is controlled by operating levers. The lifting capacity ranges from 1,000 to 15,000 pounds. The lifting capacity is determined by the center of gravity of the load in relation to the position of the forks. The weight of the forklift itself acts as a counterbalance for the weight being lifted.

The lifting heights range from 100 to 210 inches. These lifts are equipped with telescopic masts that permit loads to be lifted beyond the heights of the collapsed mast (mast at its minimum height). The mast may be tilted forward from the vertical position 3° to 5° and rearward about 10°.

Figure 7-16a shows a forklift and some of the components of the lit assembly. There are two tilt cylinders that are operated by hydraulic pressure. These cylinders control the forward and aft movement of the forks for tilting. The uprights are the main assemblies to which the other components are attached. These assemblies include the hoist cylinder, carriage, load safety rack, and forks. The hoist cylinder is the hydraulically operated control for lifting and lowering the forks. The chain and carriage assemblies assist the hydraulic hoist in lifting the forks. The forks are mounted on the lift carriage, traveling up and down with it. The forks on this particular vehicle have to be moved sideways or laterally by hand for width adjustment.

**Operation.** Approach the load squarely with the lifting forks at the correct height, spread as wide as the load permits, and spaced equally from the center of the mast to divide the load evenly. On objects of unusual shape or items that are heavier on one end than the other, the forks may have to be placed to one side of the load's center. Move forward until the forks are completely under the load. Before lifting the load, tilt the mast assembly as far backward as it will go. As soon as the load clears the ground, make sure that it is balanced and not apt to fall either forward or sideways during normal movement. It may be necessary to set the load down and reposition the forklift to assure balance or get a larger forklift to control the load. Then lift the load, but keep it close to the floor while carrying it to its new location. Always travel with the forks raised from 2 to 4 inches above the floor or ground. When a load is too high to see over, travel in reverse. Never use reverse gear as a brake.

Do not extend your hands or arms through the mast while the forklift is in operation. Be careful not to wing the rear of the lift into other objects. If you think a load is too heavy for either the lift or the capacity of the floor, correct the situation before moving it. Don't let anyone ride on the forks or any other part of the lit. When the follow another vehicle in a work area, stay at least three lengths behind in case your load should topple forward. Check overhead clearances before passing through doorways, under low beams, pipes, etc. Avoid driving over objects or holes in the floor, and slow down before driving over thresholds to prevent toppling the load or losing control of the vehicle. Avoid driving close to the edge of loading docks. Carry loads on pallets whenever possible. If the load is excessively bulky and wide, have someone else check for proper clearance.

Descend steep grades in reverse to prevent the load from toppling. Don't make sudden stops with a load. Don't bump or push stacks with the lift to straighten or move the stacks. Use general driving rules for inside as well as outside operations. Keep to the right, stop at blind intersections, and use horn and hand signals. Keep your legs within the sides of the vehicle when it is moving. Serious injuries have been caused when a driver's legs were caught between the lift and obstacles in a narrow operating area. Remember that you must watch for the safety of pedestrians and workers in your area of operation. You are entirely in charge of your vehicle. Do not stack empty pallets higher than eye level. Do not leave a gasoline-powered forklift unattended with the motor running. Not only does this cause excessive wear on the engine, but it creates excessive carbon monoxide fumes in confined areas. When you park the forklit, lower the forks until they rest on the floor or ground and set the handbrake.

**Exercises (469a):**

1. What determines the lifting capacity of forklifts?

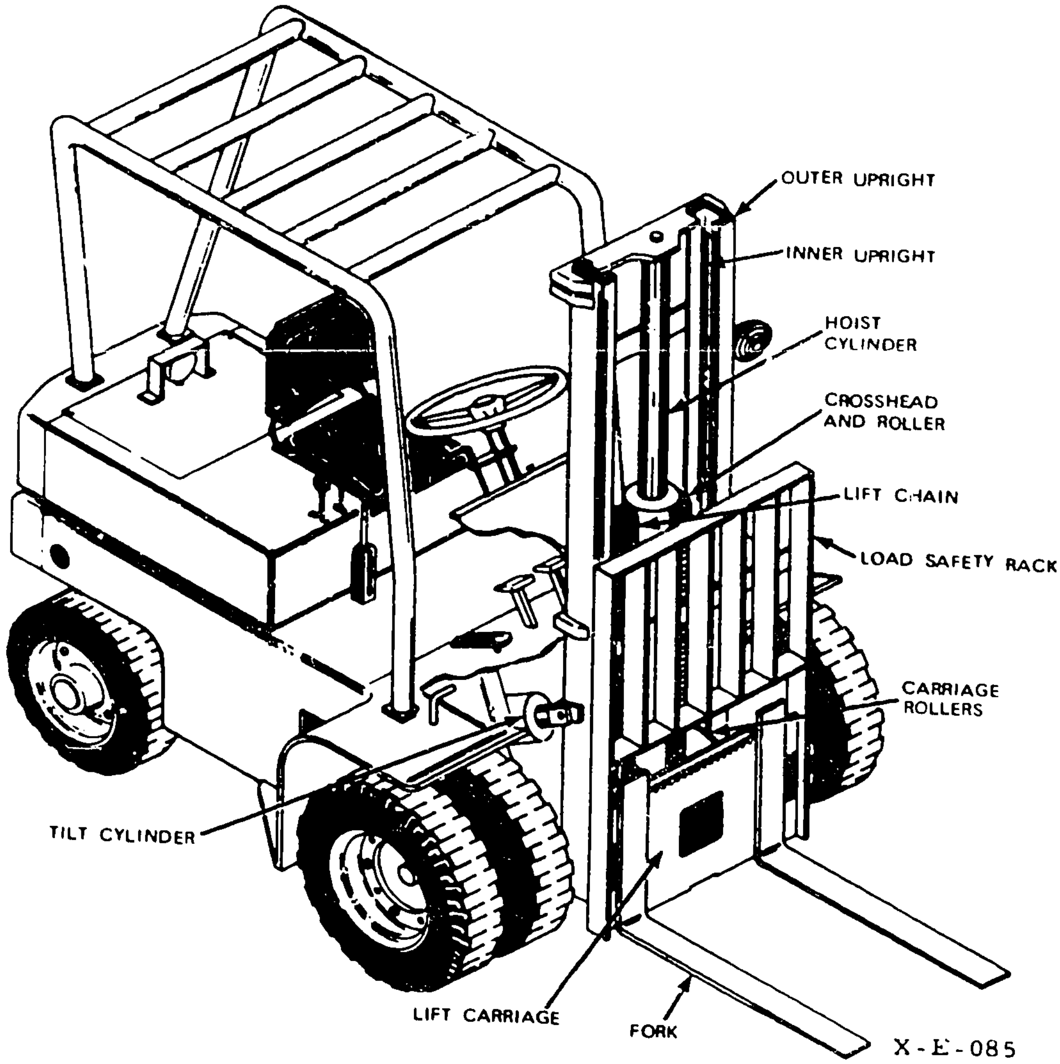


Figure 7–16a. Forklift.

2. How far can the mast be tilted forward and rearward?

3. How may the forks be moved laterally?

4. How do you lift a load with a forklift?

5. How high should the forks of a forklift be raised when moving a load?

6. How can you help to insure safe movement when moving forklift loads that restrict visibility?

7. How should steep grades be descended with a loaded forklift? Why?

8. What should you do when you leave a gasoline-powered forklift unattended?

**470. Name the types of convoys; state their advantage, disadvantages, and composition; and clarify the scheduling of halts.**

**Types of Convoys.** A convoy is the movement of a group of motor vehicles under the control of a designated individual. In many cases, a convoy is called a motor march. These two terms mean the same thing. Its purpose is to make it easier to coordinate the movement of personnel and material.

There are three kinds of convoys: normal convoys, hazardous convoys, and convoys transporting classified equipment. The normal convoy is made up of general purpose vehicles that can maintain normal speeds on the highway. Hazardous convoys are made up of large, bulky motorized equipment which is too wide, long, or slow to travel at normal highway speeds. Convoys transporting classified equipment may have normal convoy vehicles or hazardous convoy vehicles such as missile hauling trailers. Most of the time, convoys with classified equipment are small and have only one transport vehicle with the necessary escorts.

Th e types of marches may be used: close column, open colu n, and infiltration. The difference between these marches is mostly vehicle spacing. Densities and speeds will vary with such factors as weather, tactical situations, enemy capability, condition, and type of road, vehicular maintenance, and types of vehicle.

*Close column march.* Close column march formations are used when in blackout conditions or in congested areas. Elements of the march are grouped as compactly as possible to reduce road space to a minimum. Vehicles in close column follow each oher at the minimum distance which safety, traffic conditions, and the tactical situation will permit. For planning purposes, figure that vehicles move at a rate of 10 miles in the hour("in the hour" refers to distance covered and not miles per hour speedometer readings) with a density of 67 vehicles per mile of road.

The advantage of the close column march is the full traffic capacity of the road or traffic and that can be used, since road space is reduced to the minimum required for safe driving. Column control and intracolumn communications are better, and fewer guides, escorts, and markers are needed.

Some of the disadvantages are that close column formations do not provide dispersion for passive protection against enemy observation and attack. The strength and type of organization are readily apparent to hostile observation. Vehicles may arrive at loading and unloading terminals more rapidly than they can be handled. Careful scheduling and rigid control of traffic are necessary to avoid blocking intersections. Greater driver fatigue is generally experienced in close column than in other marches. Use of the highways by other traffic is severely limited.

*Open column march.* An open column march is used during daylight moves most of the time. The distance between elements is increased to gain a greater degree of protection from hostile action and to allow other traffic to use the highway at the same time. For planning purposes, figure that vehicles will move at a rate of 15 miles in the hour with a density of 20 vehicles per mile of roadway.

The advantages of open column formation is that they offer some passive protection from enemy observation and action, allow greater speeds with more safety, permit greater flexibility in moves, and reduce driver fatigue.

The disadvantages of open column formations are the difficulty in commanding and controlling them. Abnormal gaps make it hard for drivers to maintain prescribed spacing. Open column formations also permit less traffic volume on a road than more compact formations. In comparison with filtration, open columns have less secrecy and are not as well adapted to passive defense.

*Infiltration.* Infiltration is used when maximum secrecy, deception, and dispersion are needed. This type of movement involves the dispatch of vehicles to a predetermined destination over one or more routes individually or in small groups at irregular intervals and at irregular rates of march. To an observer, an infiltration move looks like ordinary casual traffic. Vehicles should normally be dispatched so as to produce an average density not to exceed eight units per hour. It is suitable for daylight moves, movement in congested areas, and on routes which cross heavily traveled roads.

Advantages of infiltration type marches are that they give the best possible defense against hostile observation and attack. Under light traffic conditions, movement of the individual vehicle is not materially affected by other vehicles in the move but is limited only by orders, road capability, vehicle mobility, and the training, experience, and physical condition of the drivers. Higher speeds by individual vehicles may be used with this type of

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449 – 7. Monthly.
449 – 8. The point of maximum potential and three points of minimum potential.
449 – 9. In Section 9 of AF Form 491.
449 – 10. Annually.

450 – 1. –0.85 volt.
450 – 2. Partial protection and may indicate that the leads to one or more anodes are broken, or the anodes are used up.
450 – 3. There is a leak on the structure.
450 – 4. Conduct coating conductance tests and/or Pearson type over-the-ground holiday detector tests. To fix the fault, excavate the line and patch the coating or install additional anodes.
450 – 5. Follow the flow of electricity through the unit.
450 – 6. Turn off the rectifier by throwing the AC circuit breaker and the outside disconnect switch.
450 – 7. The stacks may be defective and should be checked for opens or shorts.
450 – 8. Gas blockage or dry soil; or the anodes may need to be replaced.
450 – 9. Blown fuses, loose terminals, lightning damage, faulty meters, and open circuit breakers.
450 – 10. Check for shorts or overloads and repair damaged components.

CHAPTER 5

451 – 1. T.
451 – 2. T.
451 – 3. F. The signal may be audible, visual, or a combination.
451 – 4. F. They may be coded or uncoded.
451 – 5. T.
451 – 6. F. They are to notify the oc pants to evacuate.
451 – 7. T.

452 – 1. Power source, pull station, circuit conductors, and bells.
452 – 2. Closing a switch, completing a current path through the bell circuit.
452 – 3. To warn personnel when operating capability is lost.
452 – 4. Batteries.
452 – 5. Simulates an alarm activation.
452 – 6. Varying the current flow through a network of circuits.
452 – 7. Switch.
452 – 8. The contacts open.

453 – 1. The major command.
453 – 2. No. 14 AWG.
453 – 3. Conduit; raceway.
453 – 4. Line.
453 – 5. 4½.
453 – 6. Recess.
453 – 7. Maintenance; troubleshooting.
453 – 8. AFR 92–1.
453 – 9. Wiring and equipment schematic diagrams, as-built drawings, manufacturers' technical data, and system revision information.
453 – 10. Visual; operational.
453 – 11. At the termination points.
453 – 12. Break the circuit electrically in half.
453 – 13. The same type as removed.

454 – 1. To give the earliest possible notice of an attempted intrusion.
454 – 2. Control unit and its sensor components, and the monitor and display equipment.
454 – 3. Within the protected structure.
454 – 4. Battery power will automatically switch over.
454 – 5. Secure, Access, Test/Reset.
454 – 6. Motion sensor.
454 – 7. The status of the monitor cabinet power.
454 – 8. Status monitor module.

455 – 1. 20 VDC.
455 – 2. A rise in ohmic valve in the circuit.
455 – 3. It produces metal shavings.
455 – 4. Covers will be secured with a tamper switch, by tack welding, brazing, or epoxy filling, or provided with twist-off screws.
455 – 5. Power conductors NO. 14 AWG; low voltage conductors NO. 22 AWG.
455 – 6. The diagram should show the complete system, be marked Confidential, and placed in an appropriate container.
455 – 7. T.O. series 3159–4.

456 – 1. For their own protection.
456 – 2. T.O. series 315–4.
456 – 3. To indicate which group of sensors processed an alarm condition.
456 – 4. An alarm reading of 20 VDC; no alarm reading is 0 VDC.
456 – 5. Minimum of 19 VDC to maximum of 21 VDC.
456 – 6. Replacement.
456 – 7. To bring the system back on line as soon as possible.
456 – 8. Tag your conductors.

CHAPTER 6

457 – 1. X.
457 – 2.
457 – 3. X.
457 – 4.
457 – 5.
457 – 6. X.

458 – 1. Medical; dental.
458 – 2. Mental; physical.
458 – 3. Broken in.
458 – 4. Dry footwear; massage.
458 – 5. Salt.
458 – 6. Exercise.
458 – 7. Training.

459 – 1. Deserts are more often made up of rock and scrub vegetation.
459 – 2. X.
459 – 3. X.
459 – 4. Shoes should be thick and sturdy to protect from rocks and thorns.
459 – 5. X.
459 – 6. X.
459 – 7. X.
459 – 8. X.
459 – 9. Footwear should be made up of layers of clothing and should not bind or restrict circulation.
459 – 10. Blood feeding insects are a problem in artic areas in the summer only.
459 – 11. X.
459 – 12. Trench foot is more of a problem in arctic summers than winters.

460 – 1. An "X" should be placed by b, d, e, f, and g.

461 – 1. True.
461 – 2. True.
461 – 3. True.
461 – 4. True.
461 – 5. False.

CHAPTER 7

462 – 1. An "X" should be placed by a and d.
462 – 2. An "X" should be placed by c.

463 – 1.
a. Knob and tube: A positive and negative conductor bus run in an overhead space with the conductors supported on porcelain split insulators.
b. Twisted wire and cleats: Adaptation of knob and tube with a twisted pair of wires separated for bus taps by ceramic cleats.
c. Ground return, single wire: The earth is used as the neutral.

463 – 2.
a. Twisted wire and cleats.
b. Knob and tube.
c. Ground return, single wire.

464 – 1. Most foreign systems have not been installed in accordance with the NEC. This is attributed largely to material shortages.
464 – 2. Converted; mod d, inefficiently.
464 – 3. The electrician or unit commander may use foreign equipment which may be difficult to obtain or they may modify standard U.S. equipment to use with the foreign system.

464 – 4. Both lamp and ballast life will be shortened.
464 – 5. Obtain a frequency changer to use with receiving transmitting equipment. The only time this equipment should be used without a changer is in an emergency as it will not operate satisfactory either below or above the rated frequency.
464 – 6. A special joint compound must be applied to all connections or joints.

465 – 1. A walkaround inspection for the general condition of the truck.
465 – 2. Leaks of oil, fuel, hydraulic fluid, water, antifreeze, or brake fluid.
465 – 3. Cuts, wear, direction of rotation, and proper inflation.
465 – 4. Familiarize yourself with the location of the gauges, adjust the seat and mirror, and fasten the seat belt. Place the transmission in neutral with the clutch disengaged, set the brake, and turn the ignition to start.
465 – 5. The oil pressure gauge or light.
465 – 6. To allow the transmission fluid to circulate.
465 – 7. To remove condensation.
465 – 8. 3/4 tank; to reduce condensation and to have enough in case of an emergency.
465 – 9. Park or reverse.
465 – 10. Hydraulics.
465 – 11. Lay the forks flat on the ground.

466 – 1. Flats on inside duals can be changed by using a 2-inch block under the inflated tire to raise the vehicle. Block the axle and dig the dirt out from the blocked tire.
466 – 2. First, try digging the soil from in front of the wheel with a shovel, mattock, axe, or pick. If that proves unsuccessful, obtain a log or piece of heavy timber long enough to reach across the hole in front of the wheel. Fasten the log to the wheel with a chain. Apply power to the wheel; when the wheel pulls out of the hole have someone fill the hole with rock or other suitable material.
466 – 3. Back up the vehicle until the A-frame is upright.
466 – 4. Use of a properly fastened tow bar; or, if not available tie front bumper of towed vehicle tightly to the rear of the towing vehicle.
466 – 5. Skid; timber.
466 – 6. (1) Single line straight pull. (2) The one using both the spreader bar and the snatch block.
466 – 7. The shear pin will break, or the brake lining will be needlessly worn.
466 – 8. Fasten a rope between the duals on one side of the truck and those on the opposite side. Fasten the ends to anchor. When power is applied to the wheels, the rope winds up between the duals to exert a pull.
466 – 9. Use roads where your vehicle is concealed by natural vegetation; avoid dusty roads.
466 – 10. To prevent changes or markings, such as tire tracks, that would be readily apparent to the enemy.

467 – 1.
a. Hammer the broken line flat between the break and the line to the other wheel; or on a broken hose fold the end over and twist a wire around it tightly.
b. Plug the puncture with soap or a stick.
c. Loosen the generator and tie a small rope or a strand from a larger rope around the pulleys. Sometimes the ends of the broken belt can be wired together.
d. If it occurs softly after a stop, pour cold water over the fuel pump and fuel line; if water is not available, open the hood and let the engine cool. If it occurs while the vehicle is in operation, use a wet rag and wrap it around the fuel pump and sediment bowl.
e. Break the line and install a piece of hose from the windshield wiper or air horn over the two ends; an alternate method is to wrap the broken line tightly with plastic tape or other nonporous material, secured with closely wrapped wire or string.
f. Wipe off carefully all wiring and distributor, including inside cap and rotor.

467 – 2. It may cause sparks or short out the good battery.
467 – 3. To prevent sparks from igniting hydrogen gas from the batteries.
467 – 4. In the reverse order from the way originally connected.

468 – 1. On a sloping surface, locate the work to avoid extending the booms to their maximum reach ont he downhill side.
468 – 2. The lower boom will rise.
468 – 3. (1) Set truck's parking brake before operating boom.
(2) Set outriggers.
(3) Use safety belts.
(4) Close outrigger lock valves before operating boom.
(5) Operate controls slowly and smoothly.
468 – 4. Qualified operators only.
468 – 5. At the main hydraulic control valve near the base of the lower boom.

469 – 1. A boom, a winch, and a capstan.
469 – 2. A power takeoff from the line truck engine supplies the power.
469 – 3. It is equipped with an automatic brake to prevent turning under load except when the truck engine turns it.
469 – 4. 30.
469 – 5. It is used for raising loads.

469a – 1. The lifting capacity is determined by the center of gravity of the load in relation to the position of the forks.
469a – 2. The mast may be tilted forward from the vertical position 3° to 5° and rearward about 10°.
469a – 3. By hand.
469a – 4. Drive the forklift forward until the forks are completely under the load. Tilt and mast rearward as far as it will go and lift the load.
469a – 5. 2 to 4 inches.
469a – 6. By traveling in reverse.
469a – 7. In reverse to prevent the load from toppling over.
469a – 8. Turn the ignition off, set the handbrake, and lower the forks until they rest flat on the floor or ground.

470 – 1.
a. Close column march.
Advantages: Full traffic capacity of the road is used; better communication; fewer guides, escorts, and markers needed. Disadvantages: No protection from observation and attack; scheduling problems; greater driver fatigue; limits use of highway to local traffic.
b. Open column march.
Advantages: Offers more protection from attack and observation; allows greater speed; reduces driver fatigue.
Disadvantages: Problems in communication; maintaining space between elements difficult for drivers; smaller traffic volume.
c. Infiltration.
Advantages: Best defense against hostile observation and attack; higher speeds; each individual vehicle has more freedom. Disadvantages: Longer time to complete; hard to regulate; more detailed briefing required; halts more difficult to plan.

470 – 2. Head, main body, and trail.
470 – 3. The pace setter (usually the same as the slowest vehicle).
470 – 4. A detached party operates apart from the march and performs special duties in advance of or following the convoy.
470 – 5. They provide for periods of rest, personal comfort, messing, refueling, maintenance and inspection of equipment, and to allow other traffic to pass.
470 – 6. They should be scheduled to allow 10 minutes rest after each 110 minutes of running time.
470 – 7. (1) The comfort of personnel and (2) servicing facilities for vehicles.

471 – 1. The amount and type of cargo that is to be moved.
471 – 2. It is used to gather information concerning the route and the adjacent areas for planning the move.
471 – 3. Number and type vehicles needed.
471 – 4. Maps; forecasters. Fuel (or repairs, rations, water); points (or bottlenecks).

472 – 1. 60 miles.
472 – 2. 1100 hours.
472 – 3. 1130 hours.
472 – 4. 7 miles.
472 – 5. Jackson Heights.

473 – 1. Communications within a convoy can be handled with sign messages, written messages, two-way radios, sounds, and signals (such as hand and arm signals).
473 – 2. Messenger or pick-up from guide along route.
473 – 3. Signs posted on roadway.

474 – 1. The American Trucking Association, Inc.
474 – 2. State, local, and military officials, and the Director of Transportation, Headquarters USAF.
474 – 3. The base transportation officer.
474 – 4. The security officer.
474 – 5. DD Forms 1265 and 1266.

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